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The calculation of the stresses set up in a bogie frame running through a curve,

By F. LEGEIN,
CHIEF ENGINEER OF THE BELGIAN NATIONAL RAILWAY COMPANY.

Figs. 1 to 4, pp. 1548 to 1552.

There is a general tendency to believe that a bogie runs through a curve so easily that its frame is subject to no other stress than that due to the load of the vehicle, that is to say, to the vertical forces. In point of fact, the bogie-pin is a very sound joint, the friction of which has but a negligible influence on the behaviour of the frame.

In practice, however, the precaution is taken of stiffening the frame with angle brackets, or with special cross-ties, for experience has shown that these strengthening pieces are necessary in order to avoid breaking the soles or the main details of the frame. The strengthening pieces are usually based on practical results, without it being possible to take into account, by calculation, the stresses which they are intended to resist.

The stresses tending to deform the frame in a horizontal direction are due mainly to the horizontal thrusts exerted by the axles on running through the curve.

The object of this paper is to indicate a method of calculation enabling the effect of these thrusts on the behaviour of the frame to be estimated. In this calculation the effect of the forces of inertia is neglected, it being possible, moreover, to compute their action separately, and consideration is given only to the frictional forces set up at the contact of the wheels with the rail, and the resultant reactions of the wheel flanges.

The calculation of these reactions and the location of the equilibrium position of the frame under the action of these forces is made by means of the method indicated by Mr. Uebelacker (*Organ für die Fortschritte des Eisenbahnwesens*, 1903; see also, *Bulletin of the Railway Congress*, May-June 1922).

The most interesting equilibrium position, from the point of view of the present problem, is that for which the bogie « floats » in the track, that is to say, the position for which only one of the front wheels, the left one for example, engages

with the rail, and gives rise to a horizontal reaction other than a purely frictional force. This position is shown diagrammatically in figure 1.

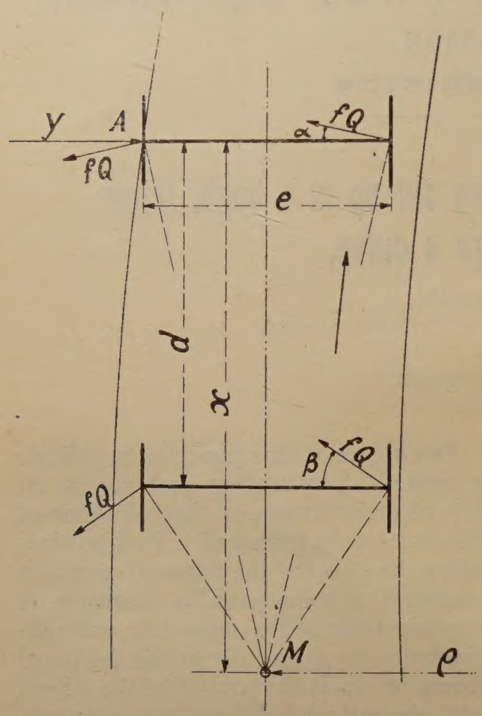


Fig. 1.

Mr. Uebelacker's theory shows that, when the vehicle is in this « floating » position, the position of the centre of friction is independent of the radius of the curve above a certain minimum radius, and that this floating position is stable up to the largest radius of curvature of the track.

In the case of a vehicle which is not braked the centre of friction M is situated on the longitudinal axis of the vehicle at a distance x, such that the resultant of the frictional forces fQ set up at the point of contact between wheels and rails passes through the point A where the front wheel engages with the outer rail. The guiding action of the rail remains the same, whatever the radius of the curve, as long as the wheel A alone engages with the rail.

The rear wheel B will engage with the inner rail when the radius of the curve is equal to

$$\rho = \frac{2xd - d^2}{2\sigma}$$

where σ is the total gauge clearance.

In the case of a bogie in which the distance between the centers of the axles is 1.80 metres, the centre of friction M for the floating position would be found to be situated at a distance

$$x = 2.23 \text{ metres.}$$

The limiting radius ρ below which the wheel B begins to engage with the inner rail, the total gauge clearance being equal to $\sigma = 35$ mm., is given by the formula

$$\rho = \frac{2 \times 2.23 \quad 1.8 - \overline{1.8}^2}{2 \times 0.035} = 68.4 \text{ metres.}$$

This calculation shows that, in practice, the floating position of the vehicle is the only one to be considered, because it is realised in a permanent manner for all curves of a radius above 68.40 metres.

So far it has been assumed, and this assumption will still be made in what follows, that the bogie is not braked. In addition, the assumption is made that the load Q is the same on each of the four wheels. It would not be very difficult to modify the calculations so as to take into consideration other assumptions, but on closer examination it will be found that the assumption that there is no braking

is most unfavourable from the point of view of the deformation of the frame.

* * *

Let

Q = the vertical load transmitted to the rail by each wheel,

f = the coefficient of friction of the tyre on the rail. In the subsequent calculations the maximum is assumed to be $f = 0.25$.

e = the distance between the axes of the rails,

d = the distance between the bogie axles,

p = the distance between the axes of the axle guards.

It is required to find the position of the centre of friction M by establishing equilibrium between the frictional forces fQ set up at the contact with the rail, and the horizontal reaction Y set up at A by the rail on the wheel tending to intersect it.

In this way we obtain two equilibrium equations :

$$Y = 2fQ\left(\cos \alpha + \cos \beta\right) \quad . \quad . \quad . \quad (1)$$

$$Y \cdot x = 2fQ\left\{\sqrt{x^2 + \frac{e^2}{4}} + \sqrt{(x-d)^2 + \frac{e^2}{4}}\right\} \quad . \quad (2)$$

These two equations in reality only contain two unknowns : Y and x. The values of α and β actually only depend upon the position of the centre of friction M, and therefore upon x.

Y and x are determined by a method of trial and error, x being given different values until one is found which satisfies the conditions of equilibrium. No difficulty whatever is presented in finding x.

It should be noted that there are a number of graphical methods, also based on trial and error, for determining the centre of friction [1].

The following, for instance, is the diagram plotted by Mr. Cuypers, engineer of the Belgian National Railway Company (fig. 2).

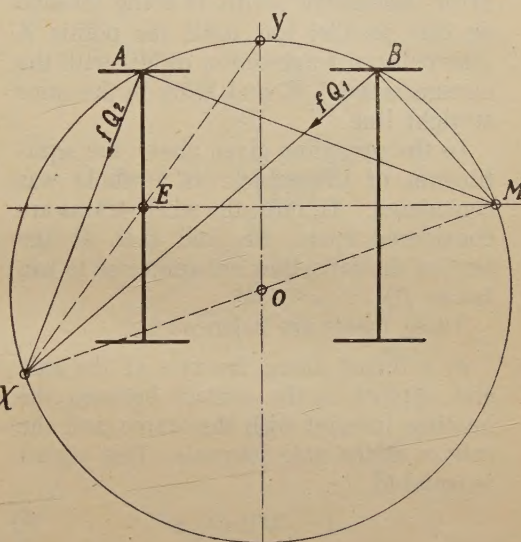


Fig. 2.

If M is the required centre of friction, the resultant of the frictional forces fQ, the wheels being assumed to be loaded equally, should pass through the centre point E of the front axle.

From considerations of symmetry, it is sufficient if the resultant of the forces fQ on the wheels A and B passes through the point E. The point of intersection x of the forces fQ and the points A, B, and M are situated on the circumference, of which MX is a diameter.

The forces fQ being equal, XE is the bisector of the angle AXB, and passes

(1) See J. Jahn, *Der Lauf von Eisenbahnfahrzeugen durch Gleiskrümmungen*, 1927.

through the point Y, dividing the arc AB into two equal parts. It will be seen, then, that the centre O of the circle corresponding to the solution of the problem is situated on a line parallel to, and equidistant from, the axes of the two axles.

The solution is obtained by trial and error, successive points O being selected on this parallel line until the points X (the point of intersection of MO with the circumference), E, and Y are in the same straight line.

In the reasoning given above, the equilibrium of the vehicle as a whole was considered. If, now, the wheel-trains are considered apart, we find that, at the level of the rails, they are subjected to two forces fQ.

These forces are balanced by :

a) a thrust along the axis of the axle and applied at the contact between the bearing, integral with the frame, and the collars of the axle journals. This thrust is equal to

$$Y - 2fQ \cos \alpha$$

for the front axle, and to

$$2fQ \cos \beta$$

for the back axle.

b) the reactions R of the axle-guards, transmitted to the journals by the bearings.

These reactions are equal to

$$R_a = fQ \sin \alpha \frac{e}{p} \quad . \quad . \quad . \quad (3)$$

for the front axle, and to

$$R_b = fQ \sin \beta \frac{e}{p} \quad . \quad . \quad . \quad (4)$$

for the back axle.

These reactions at the axle guards form a couple applied to the frame and equal to

$$fQe \, (\sin \alpha + \sin \beta).$$

This couple is balanced by another formed by the reactions of the bearings on the journals. These reactions C are therefore equal, and we have

$$C = fQ \cdot \frac{e}{d} (\sin \alpha + \sin \beta) \quad . \quad (5)$$

We have previously seen that the reaction C for the back axle is equal to $2\,fQ \cos \beta$. We have, therefore,

$$2fQ \cos \beta = fQ \frac{e}{d} (\sin \alpha + \sin \beta).$$

This last reaction in fact gives us the condition which α and β should satisfy if M is the centre of friction :

$$2 \cos \beta = \frac{e}{d} (\sin \alpha + \sin \beta) \quad . \quad (6)$$

Since the value of the ratio $\frac{e}{d}$ is known from the constructional dimensions, it is evident that the position of the centre of friction can be obtained very simply by finding the values of α and β which satisfy the equation (6).

The table given at the end of the paper will be found very helpful in finding these values.

Let us now consider the action on the frame proper. The two couples acting on the frame, as we saw in the above, may be replaced by two equal and opposite stresses directed along the diagonal of the rectangle formed by the axes of the axles and the axle-guards (fig. 3).

The component at right-angles to the long side of this stress diagonal, tending to warp the frame, is equal to $2fQ \cos \beta$. The value of the reaction can therefore be deduced at once.

From what has gone before it is evident that no difficulty is offered by the determination of the horizontal stresses to which the frame is subject when the vehicle is running through a curve. At

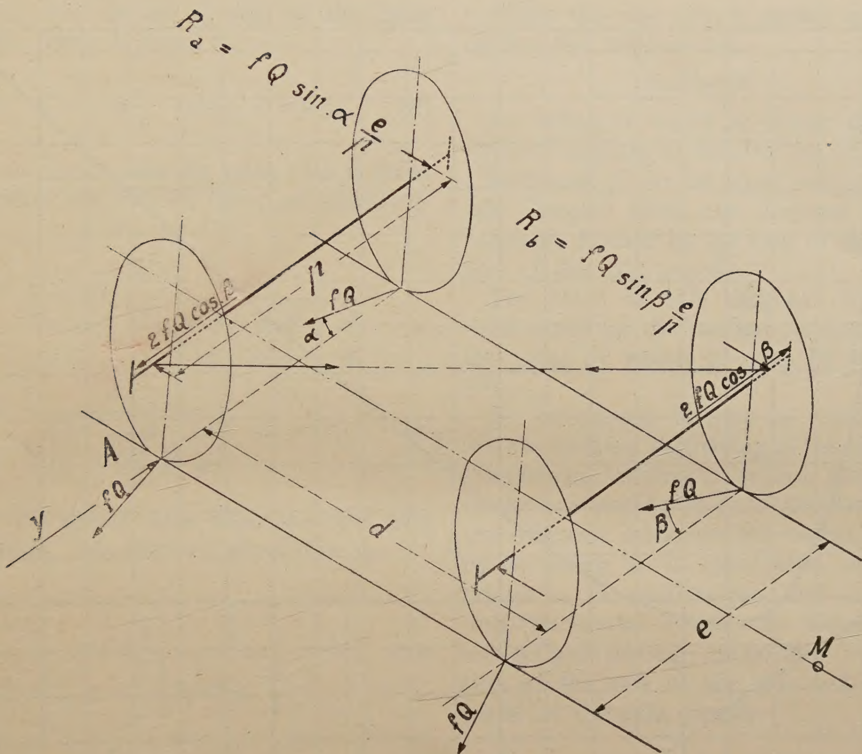


Fig. 3.

the same time the calculation gives the longitudinal and transverse reactions of the bearings on the journals.

The graph shown in figure 4 gives at once the value of x for each wheel base d of the bogie, and the corresponding value of cos β It does away with the method of trial and error which must be used if the problem is treated mathematically. The values given by this graph are obviously only applicable for curves of a radius greater than the limit value, above which the back wheel does not engage with the inner rail.

A study of the diagram giving the values of cos β shows that its value increases as the bogie wheel base diminishes, and we come to the rather unexpected conclusion that bogies with a narrow wheel base, are, other things being equal, most subject to deformation on running through a curve.

It was shown previously that the limiting radius, below which the rear axle begins to engage with the inner rail, is always small, 68.40 metres for a wheel base of 1.80 metres, and that practically it is unnecessary to consider a radius equal to or below this limit. Nevertheless if it is desired to pursue the study into this province the above-described method of calculation only requires slight modification as regards the determination of the centre of friction M.

When the rear axle engages with the inner rail, the position of the vehicle is

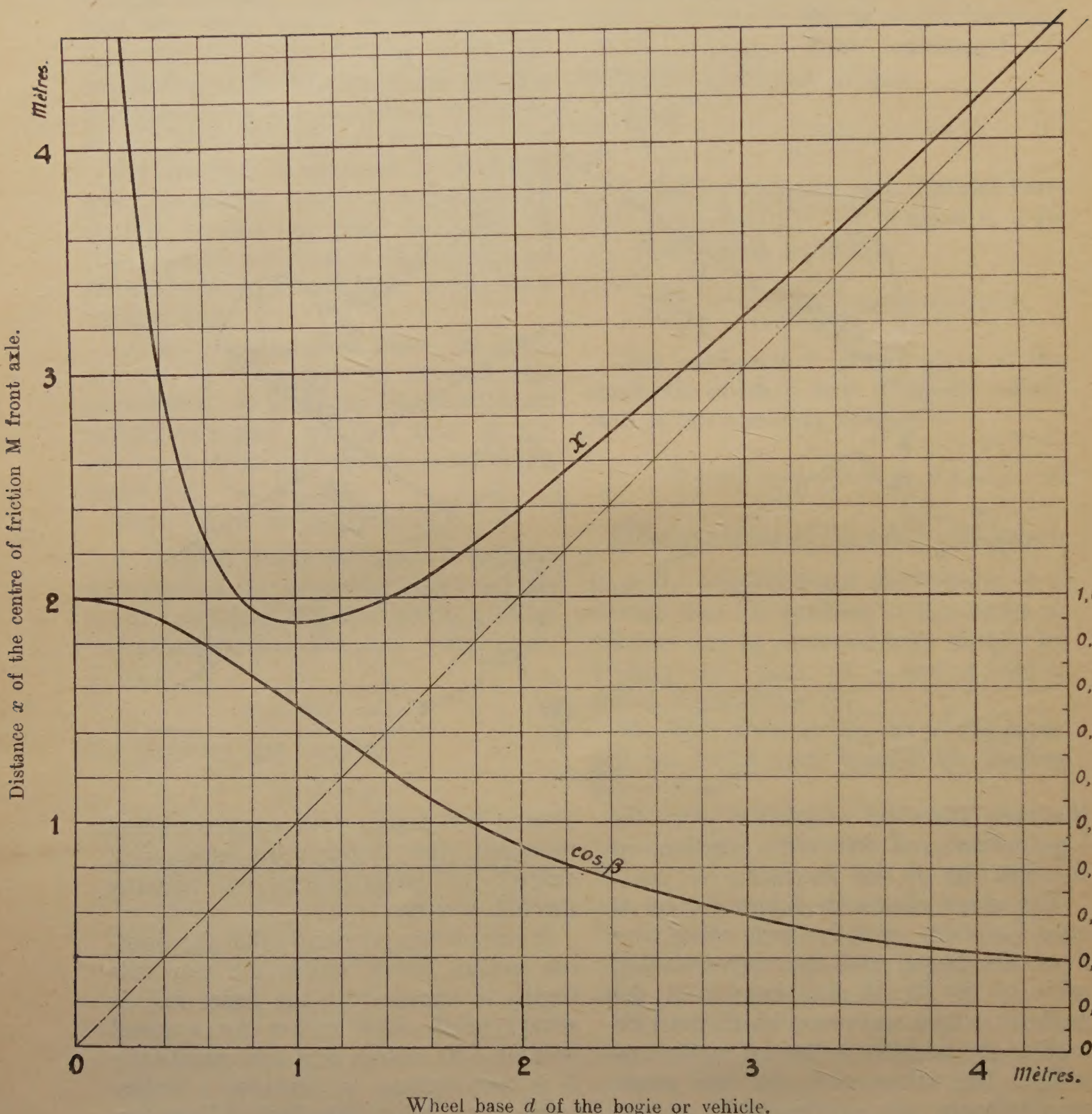


Fig. 4.

fixed geometrically, and the centre of friction is the foot of the perpendicular from the centre of the curve to the longitudinal axis of the bogie.

The following results are obtained from the geometrical relationships :

$$x = \frac{\rho\sigma}{d} + \frac{d}{2} \quad . \quad . \quad . \quad . \qquad (7)$$

The axial thrust of each of the axles on the frame is equal to

$$C = fQ\frac{e}{d} \cdot (\sin\alpha + \sin\beta) \quad . \quad (8)$$

and as in this case the value of x is fixed geometrically (7) we have, on substituting,

$$C = fQ\frac{e^2}{2d}\left[\frac{1}{\sqrt{\left(\frac{d}{2}+\frac{\rho\sigma}{d}\right)^2+\frac{e^2}{4}}} + \frac{1}{\sqrt{\left(\frac{d}{2}-\frac{\rho\sigma}{d}\right)^2+\frac{e^2}{4}}}\right] \quad . \quad . \quad . \quad . \quad (9)$$

In the special case when the rear axle is radial, this formula simplifies to :

$$C_r = fQ\frac{e}{d}\left[\frac{\frac{e}{2}}{\sqrt{d^2+\frac{e^2}{4}}} + 1\right] \quad (10)$$

When the rear axle is radial, we have in fact the relationship :

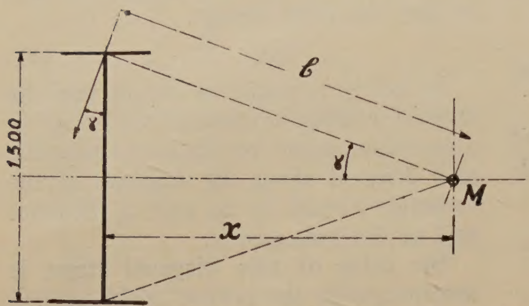
$$2\rho\sigma = d^2 \quad . \quad . \quad . \quad . \quad (11)$$

As before it would be found that the stresses tending to deform the frame in a horizontal plane are equal and opposite, and directed along the diagonal of the rectangle formed by the axes of the axles and of the axle guards.

The value of this diagonal stress is determined by the normal component C, the value of which is given by formula (9).

In conclusion it may be stated that there is nothing surprising in the fact that the stresses tending to deform the frame in the horizontal plane are directed along the diagonal, *whatever the radius of the curve,* when it is considered that the frame is in equilibrium, and that the only horizontal stresses to which it is subject pass through the point of intersection of the axis of the axle and of the plane of the axle guards.

Table for calculations relating to the passage through a curve.



x	b	$\cos \gamma$	$\sin \gamma$	x	b	$\cos \gamma$	$\sin \gamma$
Metres.				Metres.			
0.01	0 75006	0.01332	1.00000	0.31	0.81154	0.38199	0.92416
0.02	0 75026	0 02667	0.99964	0.32	0.8155	0.39240	0 91979
0.03	0.7506	0.03988	0 99921	0 33	0.8194	0.40273	0.91531
0.04	0.75106	0.05326	0.99858	0.34	0.8235	0.40841	0.91280
0.05	0 7517	0.06652	0.99778	0 35	0.8277	0.42286	0.90618
.06	0.7524	0.07974	0.99682	0.36	0.83193	0.43273	0.90155
0.07	0 75326	0.09293	0.99567	0.37	0.8363	0.44242	0.89680
0.08	0.7543	0.10605	0.99436	0.38	0 8408	0.45195	0.89206
0.09	0.7554	0.11914	0 99288	0.39	0.84534	0.46135	0.88721
0.10	0.75664	0 13216	0 99124	0.40	0.8500	0.47059	0.88235
0.11	0.75803	0 14511	0.98942	0.41	0.85475	0.47967	0.87743
0.12	0.75954	0.15799	0.98745	0.42	0.8596	0.48859	0.87250
0.13	0 7612	0.17078	0.98531	0.43	0.8645	0.49740	0.86753
0.14	0.76306	0.18347	0.98302	0.44	0.86954	0.50601	0.86251
0.15	0.7649	0.19610	0.98058	0.45	0.87465	0.51343	0.85749
0.16	0.7669	0.20863	0.97800	0.46	0.87984	0.52282	0.85244
0.17	0.76903	0.22106	0.97525	0.47	0.8851	0.53101	0.84738
0.18	0.7713	0.23337	0.97239	0.48	0.89045	0.53905	0.84230
0.19	0.7737	0.24557	0.96937	0.49	0.8939	0.54694	0.83717
0.20	0.7762	0.25766	0 96623	0.50	0.9014	0.55469	0.83206
0.21	0.77885	0 26963	0.96296	0.51	0.9070	0.56229	0.82690
0.22	0.7816	0.28147	0.95956	0.52	0.91264	0 56978	0.82181
0.23	0.7845	0 29318	0.95605	0.53	0.9184	0.57709	0.81668
0.24	0.7874	0.30480	0.95241	0.54	0.9242	0.58429	0.81160
0.25	0.7906	0.31621	0.94869	0 55	0.93016	0.59130	0.80644
0.26	0.7938	0.32753	0.94485	0.56	0.9360	0.59829	0.80125
0.27	0.7971	0 33873	0.94088	0.57	0.9420	0.60510	0.79615
0.28	0.80056	0.34975	0.93685	0 58	0.9481	0.61175	0.79105
0.29	0.8041	0.36065	0.93270	0.59	0.9543	0.61825	0.78598
0.30	0.8078	0.37137	0.92849	0.60	0.9605	0.62467	0.78089

x	b	cos γ	sin γ	x	b	cos γ	sin γ
Metres.				Metres.			
0.61	0 96675	0.63098	0.77580	0 99	1.2420	0.79710	0.60384
0 62	0.9731	0.63714	0.77077	1.00	1.2500	0.80000	0.59997
0.63	0.9795	0.64319	0.76571	1 01	1.2580	0.80287	0.59613
0.64	0 98595	0.64912	0.76069	1 02	1.2660	0.80569	0 59237
0 65	0.9925	0 65491	0.75571	1.03	1.2742	0.80835	0 58870
0.66	0.99915	0.66056	0 75078	1.04	1.2823	0.81104	0.58493
0.67	1.00575	0.66617	0.74580	1.05	1.2904	0.81370	0.58130
0 68	1.0123	0.67174	0.74080	1.06	1.2985	0.81633	0.57758
0.69	1.0193	0.67693	0.73605	1.07	1 3066	0.81892	0.57390
0.70	1.0259	0.68233	0.73105	1.08	1.3150	0.82129	0 57051
0 71	1.0325	0.68765	0.72604	1.09	1.3221	0.82360	0 56710
0.72	1.0400	0.69231	0.72160	1.10	1.3314	0.82619	0 56340
0.73	1.0465	0.69726	0.71650	1.11	1.3396	0.82861	0.55983
0.74	1.0500	0.70176	0.71245	1.12	1.3486	0.83089	0.55643
0.75	1.0610	0.70688	0.70731	1.13	1 3562	0.83321	0.55293
0 76	1.0690	0.71094	0.70326	1.14	1.3646	0.83541	0.54963
0.77	1.0750	0.71628	0.69779	1.15	1.3730	0.83758	0,54633
0.78	1.0820	0.72089	0.69363	1.16	1.3814	0.83973	0.54301
0.79	1.0893	0.72524	0.68850	1.17	1.3897	0.84191	0.53963
0 80	1.0965	0.72959	0.68392	1.18	1.3981	0.84400	0.53630
0 81	1.1040	0.73370	0.67946	1 19	1.4067	0.84595	0.53310
0.82	1.1111	0.73800	0.67479	1.20	1.4150	0.84806	0.52990
0.83	1.1185	0.74207	0.67032	1.21	1.4236	0.84996	0.52685
0.84	1.1260	0.74600	0.66595	1.22	1.4321	0 85190	0.52370
0.85	1.1337	0.74976	0.66171	1.23	1.4407	0.85375	0.52067
0 86	1.1412	0.75359	0.65734	1.24	1.4491	0.85570	0.51748
0:87	1.1485	0 75751	0.65281	1.25	1.4578	0.85746	0.51455
0.88	1 1562	0.76111	0.64861	1.26	1.4663	0.85931	0 51145
0.89	1.1638	0.76474	0.64435	1.27	1.4750	0.86102	0.50857
0.90	1 1715	0.76824	0 64016	1.28	1.4835	0.86282	0.50551
0 91	1.1793	0.77164	0.63608	1.29	1.4922	0.86449	0.50265
0.92	1.1870	0.77506	0.63187	1.30	1.5008	0.86620	0.49970
0.93	1.1947	0.77844	0.62774	1.31	1.5102	0.86790	0.49680
0 94	1.2025	0.78170	0.62365	1 32	1.5181	0.86951	0.49390
0.95	1.2104	0.78486	0.61967	1.33	1.5271	0.87105	0.49100
0.96	1.2183	0.78798	0.61570	1.34	1.5355	0.87260	0.48830
0.97	1.2262	0.79106	0.61176	1.35	1.5443	0.87413	0.48560
0.98	1.2341	0 79410	0 60779	1.36	1.5531	0.87567	0.48292

x	b	cos γ	sin γ	x	b	cos γ	sin γ
Metres.				Metres.			
1.37	1.5621	0.87712	0.48000	1.75	1.9041	0.91907	0 39400
1 38	1 5707	0.87859	0.47728	1 76	1.91315	0.91995	0.39210
1.39	1.5795	0.88003	0.47490	1.77	1.92235	0.92075	0.39016
1.40	1.5882	0.88150	0.47218	1.78	1.9316	0.92152	0.38832
1.41	1.5970	0.88291	0.46955	1.79	1.9412	0.92231	0.38648
1 42	1 6061	0.88420	0.46710	1.80	1.9500	0.92308	0.38461
1 43	1.6148	0.88556	0.46452	1.81	1.95925	0.92382	0.38280
1 44	1.6237	0.88686	0.46205	1 82	1.9685	0.92456	0.38105
1 45	1.6325	0.88821	0.45944	1.83	1.97775	0.92529	0.37938
1.46	1.6414	0 88948	0.45698	1 84	1.9870	0.92602	0.37734
1.47	1.6503	0.89075	0.45450	1.85	1.99625	0.92673	0.37575
1.48	1.6592	0.89200	0.45204	1 86	2.0055	0.92745	0.37394
1.49	1.6681	0 89323	0 44960	1.87	2.0148	0.92813	0.37225
1.50	1.6770	0.89445	0.44715	1.88	2.0241	0.92881	0.37056
1 51	1.6860	0.89561	0.44484	1.89	2 03335	0.92950	0.36881
1 52	1 6950	0.89676	0.44250	1.90	2.0427	0.93014	0.36720
1.53	1.7040	0.89789	0.44022	1.91	2.0520	0.93079	0.36555
1.54	1.7131	0.89896	0.43803	1.92	2.0613	0.93145	0.36386
1.55	1.7221	0.90006	0.43577	1.93	2 0706	0.93210	0.36220
1.56	1.7311	0.90116	0.43348	1.94	2.0801	0.93272	0.36060
1.57	1.7401	0.90225	0.43122	1.95	2.0893	0.93333	0.35902
1.58	1.7490	0.90337	0.42887	1.96	2.0986	0.93395	0.35741
1.59	1.7580	0.90444	0.42660	1.97	2 1081	0.93455	0.35583
1.60	1.7671	0 90548	0.42440	1.98	2.1173	0.93515	0.35427
1.61	1.7761	0.90648	0.42224	1.99	2.1267	0.93572	0 35275
1.62	1.7852	0.90746	0.42013	2.00	2.1360	0.93633	0.35111
1.63	1.7943	0.90843	0.41805	2.01	2.1454	0 93689	0.34964
1.64	1.8034	0 90939	0.41595	2.02	2.1548	0.93746	0.34808
1.65	1.8125	0.91034	0.41386	2.03	2.1641	0.93803	0.34655
1.66	1.8216	0.91129	0.41175	2.04	2.1735	0.93857	0.34508
1.67	1.8307	0.91222	0.40970	2.05	2.1829	0.93912	0.34358
1.68	1 8398	0.91314	0.40765	2.06	2.1923	0.93965	0.34213
1.69	1.8490	0.91401	0.40570	2.07	2 2017	0.94018	0.34068
1 70	1 8581	0.91491	0.40366	2.08	2.2111	0.94071	0 33921
1.71	1 86725	0.91579	0.40166	2.09	2 2205	0.94123	0.33777
1.72	1.8764	0 91665	0.39970	2.10	2 2299	0.94175	0.33630
1.73	1.8856	0.91748	0.39778	2.11	2.2393	0 94226	0 33487
1.74	1 8948	0.91830	0.39589	2.12	2.24875	0.94272	0 33358

x	b	cos γ	sin γ	x	b	cos γ	sin γ
Metres.				Metres.			
2.13	2.2582	0.94323	0.33213	2.51	2.61966	0.95814	0.28632
2.14	2.2676	0 94370	0.33079	2.52	2.62925	0.95845	0.28527
2.15	2.2771	0.94418	0.32942	2.53	2.63883	0.95876	0.28422
2.16	2.2865	0.94468	0.32800	2.54	2.6484	0 95907	0.28318
2.17	2 2960	0.94513	0.32664	2.55	2.6580	0.95937	0.28215
2 18	2.3054	0 94561	0.32529	2.56	2.6676	0.95966	0.28114
2.19	2.3149	0.94605	0.32403	2.57	2.6772	0.95996	0.28013
2.20	2.3245	0.94647	0.32279	2.58	2.6868	0.96025	0.27912
2 21	2.3338	0.94695	0.32139	2.59	2.6964	0.96054	0.27813
2.22	2.3433	0.94738	0.32011	2.60	2.7060	0 96083	0.27714
2.23	2.35275	0.94783	0.31876	2.61	2.71562	0.96111	0.27617
2.24	2.3622	0.94827	0.31747	2.62	2.72523	0.96139	0.27518
2.25	2.3717	0.94869	0.31620	2.63	2.73485	0.96166	0.27424
2.26	2.3812	0.94910	0.31499	2.64	2.74447	0 96193	0.27330
2.27	2.3907	0.94951	0.31375	2.65	2.7540	0.96223	0.27235
2.28	2.4002	0.94992	0.31250	2.66	2.7637	0.96247	0.27139
2.29	2.4097	0.95032	0.31126	2.67	2.77334	0.96274	0.27042
2.30	2.4192	0.95073	0.31003	2.68	2.7830	0.96299	0.26950
2.31	2.4287	0.95113	0.30880	2.69	2.79256	0.96326	0.26857
2.32	2.4382	0.95152	0.30758	2.70	2.80223	0.96352	0.26762
2.33	2.44775	0.95189	0.30645	2.71	2.81187	0.96377	0.26675
2.34	2.45725	0.95228	0.30532	2.72	2.8215	0.96403	0.26587
2.35	2 4668	0.95265	0.30406	2 73	2.83115	0.96427	0.26493
2.36	2.4763	0.95303	0.30287	2.74	2.8408	0.96452	0 26401
2.37	2.48585	0.95339	0.30177	2 75	2.85045	0 96476	0.26314
2.38	2.4954	0.95375	0.30060	2.76	2.8601	0.96500	0.26226
2.39	2.5049	0.95413	0.29939	2.77	2.86973	0.96524	0.26135
2.40	2.51446	0.95448	0.29827	2.78	2.8794	0.96548	0.26047
2.41	2.5240	0.95483	0.29716	2.79	2.88905	0.96572	0.25959
2 42	2.53355	0.95518	0.29603	2 80	2.8987	0.96595	0.25875
2 43	2.5431	0.95552	0.29493	2 81	2.90837	0.96618	0.25787
2.44	2.55267	0.95586	0.29382	2.82	2.91803	0.96641	0.25701
2.45	2.56223	0.95619	0.29302	2 83	2.9277	0.96663	0.25617
2.46	2.5718	0.95653	0.29163	2.84	2.93736	0.96685	0.25533
2 47	2.5794	0.95689	0.29045	2.85	2.94702	0.96707	0.25452
2.48	2.5909	0.95719	0.28947	2.86	2.9567	0.96729	0.25368
2.49	2.6005	0 95751	0.28840	2.87	2.96638	0.96751	0.25282
2.50	2.6101	0.95782	0.28736	2.88	2.97606	0.96772	0.25211

x	b	cos γ	sin γ	x	b	cos γ	sin γ
Metres.				Metres.			
2.89	2.98573	0.96794	0.25126	3.27	3.35490	0.97469	0.22357
2.90	2.9954	0.96815	0.25038	3.28	3.36465	0.97484	0.2293
2.91	3.0051	0.96836	0.24958	3.29	3.37440	0.97499	0.22226
2.92	3 01478	0.96856	0.24876	3.30	3.38415	0.97513	0.22163
2.93	3.0245	0.96876	0 24801	3.31	3.39390	0.97528	0.22098
2.94	3.03417	0.96896	0.24720	3.32	3.40365	0.97542	0.22037
2.95	3.04384	0.96916	0.24644	3.33	3.41341	0.97556	0.21970
2.96	3.05354	0.96936	0.24562	3 34	3.42317	0.97570	0.21913
2.97	3.06323	0.96956	0.24486	3.35	3.43293	0.97584	0.21847
2.98	3.07293	0 96976	0.24406	3.36	3.44269	0.97598	0.21786
2.99	3.0826	0 96996	0.24325	3.37	3.45245	0.97612	0.21725
3.00	3.09232	0.97015	0.24249	3.38	3 46221	0.97626	0.21657
3.01	3.1020	0.97034	0.24178	3.39	3.47197	0.97639	0.21601
3.02	3.11172	0.97053	0.24100	3.40	3.48174	0.97652	0.21543
3.03	3.12144	0.97071	0.24027	3.41	3.49150	0.97666	0.21479
3.04	3 13116	0.97089	0 23954	3.42	3.50127	0.97679	0.21422
3.05	3.14086	0.97108	0.23874	3 43	3 51104	0.97692	0.21360
3.06	3.15057	0.97126	0.23801	3 44	3.52081	0.97705	0.21303
3.07	3.16028	0.97144	0 23728	3.45	3.53058	0.97718	0 21241
3.08	3 1700	0.97161	0.23660	3.46	3.54035	0.97730	0.21184
3.09	3.18972	0.97179	0.23585	3.47	3 55012	0.97743	0.21127
3.10	3.18944	0.97196	0.23514	3.48	3 55989	0.97756	0.21067
3.11	3.19916	0.97213	0.23446	3 49	3.56967	0 97768	0.21010
3 12	3.20888	0.97230	0.23373	3.50	3.57945	0.97780	0.20953
3 13	3.2186	0.97247	0.23304	3.51	3.58923	0.97793	0.20896
3.14	3.22833	0.97264	0.23231	3.52	3.59901	0.97805	0.20839
3.15	3.23806	0.97281	0.23160	3 53	3.60879	0.97817	0.20782
3.16	3.24779	0.97297	0.23094	3.54	3.61858	0.97828	0.20729
3.17	3.25752	0.97314	0.23021	3.55	3.62836	0.97840	0.20672
3.18	3.26725	0.97330	0 22953	3.56	3.63815	0.97852	0.20615
3.19	3.27697	0.97347	0.22882	3.57	3.64793	0.97864	0.20558
3.20	3.2867	0.97363	0.22816	3.58	3.65772	0.97875	0.20507
3.21	3.29644	0.97378	0.22750	3.59	3.66751	0.97887	0.20450
3.22	3.30609	0.97393	0.22685	3.60	3.67730	0.97898	0 20398
3.23	3.31593	0.97409	0.22616	3.61	3.68709	0.97909	0.20341
3.24	3.32567	0.97424	0.22552	3.62	3.69688	0.97920	0.20288
3.25	3.33541	0.97439	0.22487	3.63	3.70667	0.97932	0.20232
3 26	3.34516	0 97454	0 22422	3.64	3.71646	0.97943	0.20179

x	b	cos γ	sin γ	x	b	cos γ	sin γ
Metres.				Metres.			
3.65	3.72626	0.97954	0.20127	4.03	4.09919	0.98312	0.18298
3.66	3.73606	0.97964	0.20074	4.04	4.10902	0.983203	0 18253
3.67	3.74585	0 97975	0.20022	4.05	4.11885	0.98328	0 18210
3.68	3.75565	0.97986	0.19970	4.06	4.12869	0 98336	0.18166
3.69	3.76545	0.97997	0.19913	4.07	4.13852	0.98344	0.18123
3.70	3.77525	0.98007	0.19865	4.08	4.14836	0.98352	0.18081
3 71	3.78505	0.98018	0 19812	4.09	4.15819	0.98360	0.18035
3.72	3.79485	0.98028	0.19761	4.10	4.16803	0.98368	0.17995
3.73	3.80465	0 98038	0 19714	4.11	4.17787	0.983755	0.17952
3 74	3.81446	0.98048	0.19662	4.12	4.18771	0.98383	0.17909
3.75	3.82426	0.98058	0.19614	4 13	4 19755	0.983905	0.17873
3.76	3 83407	0.98068	0.19561	4.14	4.20739	0.98398	0 17829
3.77	3.84388	0.98078	0.19514	4 15	4.21723	0.984055	0.17785
3.78	3.85369	0.98088	0.19461	4.16	4.22707	0.98413	0 17743
3.79	3.86350	0.980976	0 19413	4.17	4.23691	0.984205	0.17705
3.80	3 87331	0 981073	0.19368	4.18	4 24675	0 98428	0 17663
3.81	3.88312	0.981168	0.19318	4.19	4.25659	0.984355	0.17620
3.82	3.89293	0.981264	0.19267	4.20	4.26643	0.98443	0.17577
3.83	3.90274	0 981359	0.19218	4.21	4.27628	0.98450	0.17537
3.84	3 91256	0.981455	0 19170	4.22	4.28613	0.98457	0.17498
3.85	3.92237	0.981548	0.19122	4 23	4.29598	0 98464	0.17463
3.86	3 93219	0.981641	0.19072	4.24	4.30583	0.98471	0 17422
3.87	3.9420	0.981734	0.19027	4.25	4.31567	0.98478	0.17381
3 88	3.95181	0.981828	0 18977	4.26	4.32552	0 98485	0.17342
3 89	3 96163	0.981914	0.18931	4.27	4.33537	0 98492	0.17302
3 90	3 97145	0.98201	0.18881	4.28	4.34522	0.98499	0.17262
3.91	3.98127	0 982098	0.18836	4.29	4.35507	0.985058	0.17223
3.92	3.99109	0.982185	0.18792	4.30	4.36492	0 98513	0.17176
3.93	4.00092	0.98227	0.18748	4 31	4.37477	0.985193	0.17146
3.94	4.01075	0.98236	0.18700	4.32	4.38462	0 985260	0.17107
3.95	4.02057	0.982445	0.18655	4 33	4.39447	0.985330	0.17084
3.96	4.03039	0 98253	0.18610	4.34	4 40432	0.985396	0 17029
3.97	4.04022	0.982615	0.18564	4.35	4.41418	0 985460	0.16992
3.98	4.05005	0.98270	0.18521	4.36	4.42404	0.985524	0.16957
3 99	4.05987	0.982787	0.18470	4.37	4.43389	0.985590	0.16918
4.00	4.06970	0 982874	0.18427	4.38	4.44374	0.985656	0 16881
4 01	4 07953	0.982956	0.18386	4.39	4.45360	0.985720	0.16837
4.02	4.08936	0.98304	0.18338	4.40	4.46346	0.985782	0.16803

[625. 143. (01]

Note on the calculation of rails for high speeds,

By F. CORINI,

ENGINEER,

PROFESSOR IN THE « R. SCUOLA D'INGEGNERIA », BOLOGNA.

In the June number of this review there appeared an article by Mr. Stoïka under the title, « Notes on the calculation of rails for high speeds », which included some comments on my paper of December 1928, on the same subject .

I am glad to see that my paper has aroused interest, and it would appear opportune to add a few explanatory remarks on this subject, not for the sake of argument, but in order to make more clear certain points which might serve as a basis for discussion at a future session of the Congress.

At the beginning of my previous paper attention was called to the very serious difficulties of an analytical nature which are encountered in attempting an exact solution of the dynamic problem of the deformation of rails. A previous paper was also quoted in which I recalled the paper by the engineer Willame published in the *Bulletin of the Railway Congress* for August 1914. The definition given by Mr. Stoïka for the elastic curve of the rail produced solely in the immediate neighbourhood of the axle is given in its entirety by the formula (1)

$$\eta = (M \sin \alpha\xi + N \cos \alpha\xi)e^{-\beta\xi} \quad (1)$$

which represents the deformation η of the rail in a vertical plane in terms of the distance ξ from the load. The axes ξ and η, with the origin Ω, moving with the same speed as the load, were adopted. M and N are functions of the load and of ξ and depend upon the mass of unit length of the track, the modulus of elasticity of the rails, the coefficient of compressibility of the ground, and the speed.

The factor $e^{-\beta\xi}$ is a reduction coefficient if β is real, that is to say, if the speed is lower than a given value representing the limiting speed. The reduction of the elastic curve (which has exactly the shape of a flattened sinusoidal curve) diminishes as the speed increases. It is zero for a speed equal to the limit, and for speeds greater than the limit the deformation increases instead of diminishing.

Such is the phenomenon when looked at as a whole. It is, however, precisely because it lends itself with difficulty to a concrete calculation, that we have to be satisfied with approximate solutions. Moreover, it should be pointed out that, in order to obtain the analytical results referred to previously, it was necessary to make a simplifying assumption to the effect that the support of the rail is continuous. If it had been assumed that the support was discontinuous (rails on sleepers), the formulæ would have been

(1) « La velocitá limite nelle ferrovie ». (The limiting speed on railways) *Bollettino del Collegio Nazionale degli Ingegneri Ferroviari Italiani.*)

still more complicated and the difficulties still greater.

The approximate solution which was selected consisted in regarding the load as travelling not along a horizontal straight line, but along a pseudo-sinusoidal curve. As a consequence, consideration was given to the centrifugal force on the load for which the curvature produced is a maximum, and for which the direction of the centrifugal force tends to be added to the weight.

Mr. Stoïka now raises the following objection. If the elastic deformation of the rails is taken into account, the point of contact of the wheel and rail describes the geometrical locus of the maximum depressions at that place. In short, he asserts that this is a straight line parallel to the plane of the track.

If such was the case, and neglecting the vibrations of the rail, the deduction which he makes, namely, that there is no necessity to take into consideration the centrifugal force in the vertical plane, would be exact. But this is not what occurs.

When the load is situated in the centre of a span, the maximum depression is equal to the depression of the supports plus the depression due to the deformation proper of the rail. If we denote by y the depression of a point situated at the distance x from the nearest support, we have, according to the first hypothesis of Schwedler :

$$\frac{d^2 y}{dx^2} = \frac{1}{EJ}\left(M_2 + \frac{P}{2} x\right) \quad \ldots \quad (2)$$

$$y_m = \frac{P_2}{D} + \frac{6\gamma}{D} P \left(\frac{4\gamma - 3}{10 + 4\gamma} \frac{d}{32} - \frac{1}{96}\right) + C \frac{d}{2} \quad \ldots \quad (3)$$

When the load is situated above a sleeper (second hypothesis of Schwedler) we have :

$$y_2 = \frac{P'_2}{D} \quad \ldots \quad (4)$$

In the first and second hypotheses the two values of P_2 differ but little from each other, and y_m is greater than y_2 by the sum of the second and third terms of the second member of expression (3). Consequently, the locus of the extremities of the maximum depressions is not a straight line parallel to the plane of the track, but is a curve which, in the centre of the span, has the same curvature as the elastic curve of the rail, corresponding to the first hypothesis of Schwedler.

Moreover, the assumption that the course followed by the load in a vertical plane is sinusoidal is commonly accepted by every author who has studied the abnormal movements of railway vehicles.

The paper by Timoshenko, to which Mr. Stoïka makes references, has for its object the determination of the rolling friction, and cannot therefore be taken as a basis for solving the present problem [1].

[1] Vide Corini : « Sull altrito volvente nei veicoli ordinari e ferroviari. » (The rolling friction of ordinary and railway vehicles). *Monitore Tecnico*, 1925.

We shall not stop to discuss the question of the « critical speed », raised by Mr. Stoïka, for such a discussion would be outside the scope of these brief remarks. It may be pointed out merely that the critical speed ought to correspond to values of an order of magnitude rather greater than the given value, and depending upon the resonance phenomena in the rail vibrations.

Bologna, 26 April 1929.

[621 .132 8]

REPORT No. 2

(British Empire, China and Japan)

ON THE QUESTION OF LOCOMOTIVES OF NEW TYPES; IN PARTICULAR TURBINE LOCOMOTIVES AND INTERNAL COMBUSTION MOTOR LOCOMOTIVES (SUBJECT V FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) [1],

By R. E. L. MAUNSELL,

CHIEF MECHANICAL ENGINEER, SOUTHERN RAILWAY (GREAT BRITAIN).

Figs. 1 to 3, pp. 1564 to 1568.

The Questionnaire on this subject which was divided into three main sections, as follows :

a) Turbine locomotives and steam reciprocating engines which are not directly connected to the coupled wheels,

b) Internal combustion locomotives,

c) Locomotives having boilers of special design,

was addressed to 37 Administrations, and 32 replies were received, as indicated in the summary given.

In no case was any locomotive coming within the terms of the questionnaire reported as being actually in service, other than rail cars or small shunting locomotives, but the following Administrations reported that experimental locomotives were either contemplated or on order.

a) In the case of turbine locomotives, the *London Midland & Scottish Railway* reports the trial of an experimental Ljungström turbine locomotive on behalf of the makers, Messrs. Beyer, Peacock & Co., by whom the following particulars were supplied. The adoption of a turbine locomotive is not reported by any railway administration.

Ljungström Turbine Locomotive.

A turbine locomotive suitable for normal express services on British Railways, has been constructed by Messrs. Beyer, Peacock & Co. Ltd., of Gordon Foundry, Manchester (see diagram fig. 1). It consists of two sections of approximalely the same wheel base each. The first section carries the boiler and its auxiliaries, while the second section bears the turbine and its reduction gearing and the condenser, with its auxiliaries.

An ordinary locomotive type boiler is used, having a working pressure of 300 lb. per square inch and this is mounted on plate frames. It is carried by a leading bogie followed by three rigid axles. On the same frame are side tanks carrying 600 gallons of water and in the rear of the closed-in cab is a

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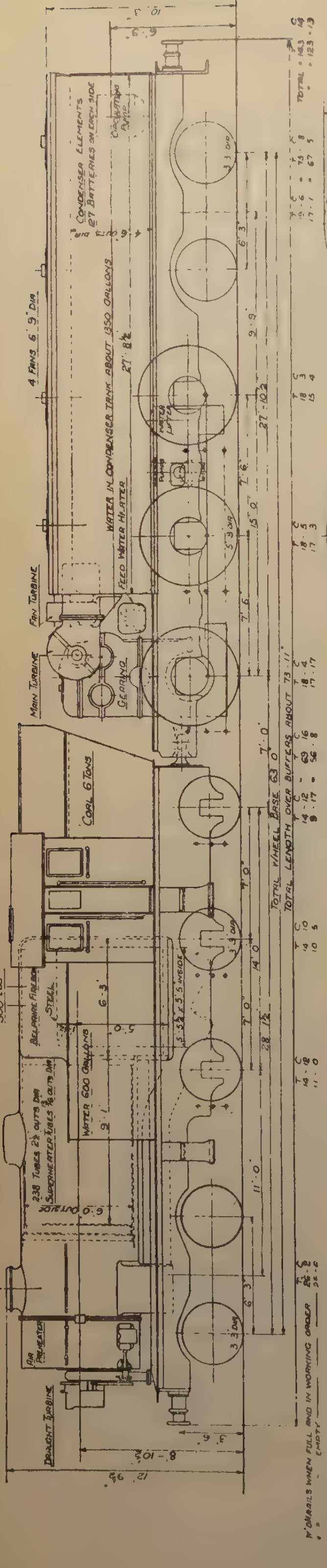
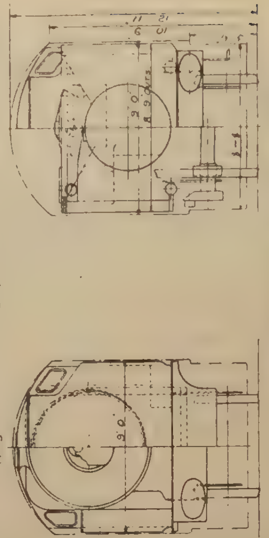
[1] This question runs as fallows : « Locomotives of new types; in particular, turbine locomotives and internal combustion motor locomotives. Construction, efficiency, use und repair. »





Gauge of rails:	4 ft. 8 1/2 in
Heating surface, tubes	1 480 square feet
— firebox	140 —
— superheater	640 —
Total	2 260 square feet.
Grate area:	30 square feet.
Heating surface of air preheater, about	13 500 —
Cooling surface of condenser, about	13 500 —
H. P. of main turbine	2 000
Tractive effort (max.) about	33 000 lb.
Maximum speed about	75 miles per hour.

Combined steam and handbrakes on boiler vehicle.
Vacuum brake on condenser vehicle and for train.

Fig. 1. — Turbine condenser locomotive, Ljungström system, for British Railways, built by Messrs. Beyer, Peacock & Co. Ltd., Manchester.

bunker holding 6 tons of coal. As there is no exhaust steam to create a draught, a small turbine-driven exhaust fan is mounted on the front of the smokebox and this draws the products of combustion from the firebox through the tubes and discharges them from the chimney. Incorporated in the smokebox is an air preheater consisting of a rotating ring of thin corrugated metal of which one portion of the circumference is exposed to the smokebox gases, while the lower portion is brought into contact with the incoming air at the front of the smokebox. The ring is revolved by gearing from the draught turbine, and an exchange of heat takes place, the heat from the smokebox being transferred to the air for combustion by contact with the metal ring as it alternately passes from the hot region to the cold and back again.

A duct carries the warm air to the ashpan under the exhausting action of the fan. Louvre shutters in the front of the smokebox control the inlet of air.

The second section also has a plate frame, and three coupled axles with 5 ft.-3 in. diameter driving wheels are arranged at the front end and a bogie behind. Outside bearings are provided for the coupled wheels and the axles are extended to carry outside cranks as in double framed engines. Compensation is provided for the spring gear of all rigid axles on the first and second sections. The main turbine is mounted over the leading coupled wheel and is of the well known Ljungström type, having a maximum speed of 10 500 revolutions per minute, corresponding to an engine speed of 75 miles per hour, the brake horse power at full pressure being 2 000. Triple reduction gearing is interposed between the turbine and driving axle, the final connection being through an elastic

quill drive. Reversing is effected by throwing an idle wheel into gear.

The condenser is arranged behind the turbine and gears, and the principal component is a large cylindrical vessel which also serves as a water tank holding 1 350 gallons. Carried on each side are top and bottom headers, connected to the condenser by branches. Between the headers cooling elements consisting of flattened tubes are carried vertically, and there are 127 batteries of these on each side. Arranged above the main condenser are four large circulating fans working on a vertical axis, and these draw large volumes of air through the nests of thin cooling tubes, thereby condensing the steam inside them. The fans are driven by a horizontal shaft through bevel gears, the motive power being a 300 B. H. P. turbine.

In addition to this a centrifugal pump lifts the water in the condenser on to a tray, from which it is sprayed over the incoming steam. This pump is vertical and is driven off the same shaft as the fans by means of a bevel gear. Air is collected in a blanked off portion of the cooling tubes at the leading end, and an ejector discharges the air to atmosphere.

There are two feed pumps of the centrifugal type driven by turbines through gearing. The feed is heated on its way to the boiler by a two-stage heater which derives its heat from steam escaping past the glands, from the air ejector for vacuum brake and the exhaust of the feed pump.

The engine has undergone extended trials on the London Midland & Scottish Railway, the maximum load hauled in regular service being about 750 tons up a 3-mile grade of 1 in 120 at a speed of about 20 miles per hour.

On a trial run with a 400-ton passenger train, a drawbar horse power of 1 200 was recorded, and the highest speed recorded was 76 miles per hour.

With 500-ton trains the coal consumption averaged 0.11 lb. per ton-mile (excluding engine) and the water consumption was about 4 gallons per mile.

The difference in capital cost on a basis of 10 engines would be about 70 % greater than a normal locomotive. No figures are available for cost of repairs and maintenance, etc.

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* *

The following Administrations report that they have in use or on order one or more « Sentinel-Cammell » or other steam rail coaches or « Sentinel » locomotives :

Administration.	Description.	Number in use.	Number proposed or on order.	Makers.	Remarks.
London, Midland & Scottish Railway, (Northern Counties Committee).	Locomotive.	1	...	Sentinel.	...
Nigerian Railway . . .	Coach.	...	1	Sentinel-Cammell.	...
Great Indian Peninsula Railway.	Coach.	3	...	Do.	...

Administration.	Description.	Number in use.	Number proposed or on order.	Makers.	Remarks.
North Western Railway (India).	Coach.	Several.	...	Sentinel-Cammell.	...
	Locomotive.	1	...	Sentinel.	...
Federated Malay States Railways.	Coach.	...	Several.	Not stated	...
London & North Eastern Railway.	Coach.	44	...	Sentinel-Cammell.	24 chain-driven. 20 gear-driven.
	Coach.	11	...	Clayton.	...
	Locomotive.	1	...	Sentinel.	...

The latest form of « Sentinel-Cammell » steam rail car is carried on two bogies, one pair of wheels of the bogie at the engine end being the driving pair. The engine is fixed to the underframe below the floor, the cylinders being horizontal and the crank shaft lying lengthways with the car. This is connected to the driving axle by a Cardan shaft and gearbox fixed on the axle. The boiler is carried on the underframe at the end of the car and is of the usual « Sentinel » water tube construction, the working pressure being 300 lb. per square inch. A coil superheater raises the temperature of the steam to about 650° F. The engine has a closed crank chamber and there are six single-acting cylinders operated by poppet valves. The sliding cam shaft for the valves has three positions in fore and back gear, giving cut off of approximately 70, 45 and 25 %.

b) The *London & North Eastern Railway* (England) contemplate putting into service a Diesel-electric locomotive, a brief description of which is as follows :

Diesel-electric locomotive, London & North Eastern Railway.

This experimental locomotive (see diagram fig. 2) is being prepared by the conversion of one of the existing electric locomotives of the Newport and Shildon electrified line.

These are eight-wheeled, double bogie engines, and electric motors drive each of the four axles independently of one another.

The power unit to be installed consists of a Beardmore variable speed Diesel engine of 1 000 B. H. P. coupled to an 800-volt D. C. generator, separately excited by an auxiliary generator. This supplies current to the four series D. C. traction motors, which are geared to the axles in the ratio of 1 to 4.5. The motors are permanently connected in parallel and are force ventilated.

The light sheet steel body of the locomotive is mounted on a straight frame of box girder construction, which is carried on two four-wheeled articulated bogies fitted with draw and buffing gear, so that

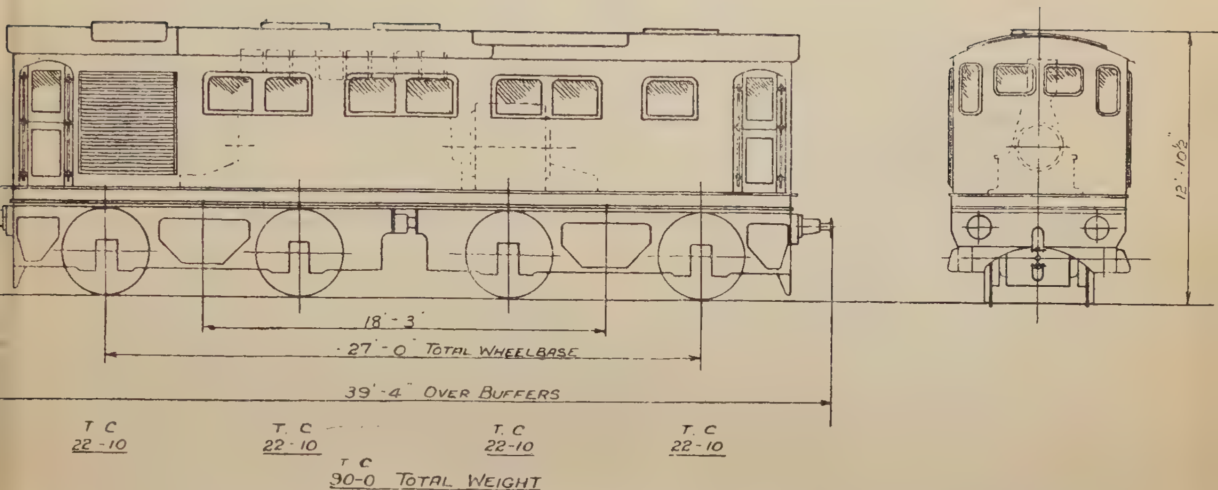


Fig. 2. — Electric freight locomotive converted to Diesel-electric working, London & North Eastern Railway.

no draw or buffing stresses are transmitted through the main frame.

A driving position is located at each end of the locomotive, and the control is all-electric. This acts upon the governor of the Diesel engine and on the field of the generator. Reversing is accomplished through the reverse handle of the master controller operating a drum type reverser, which connects the traction motor armatures and their fields in the opposite relation.

Low tension current of constant voltage is supplied through the auxiliary generator and a battery. A standard motor-driven pump for operating the continuous brake takes its current from this supply.

No arrangement is made for train heating.

The locomotive weighs 90 tons, all of which is available for adhesion. The maximum starting effort is 40 000 lb. — approximately 18 tons. The continuous rating is 775 H. P. at rail at 27 miles per hour.

The engine will be used in heavy main line goods and mineral traffic at present worked by 2-8-0 type steam locomotives.

The Japanese State Railways report that they have placed orders in Germany for one Diesel locomotive and one Diesel-electric locomotive, with regard to which they supply the following particulars :

Diesel-electric locomotive, Japanese Government Railways.

A Diesel-electric locomotive of the 2-6-2 type (see diagram fig. 3) is under construction in Germany at the Esslingen Works, to the specification of the Japanese Government Railways. A M. A. N. Diesel engine is directly coupled to a 750-volt D. C. shunt generator, independently excited by a separate generator driven through toothed gears. The engine is 6-cylinder, single-acting and of the marine type with mechanical fuel injection. Starting is by means of compressed air, obtained through a compressor driven by the main engine. There are two motors, one on each side

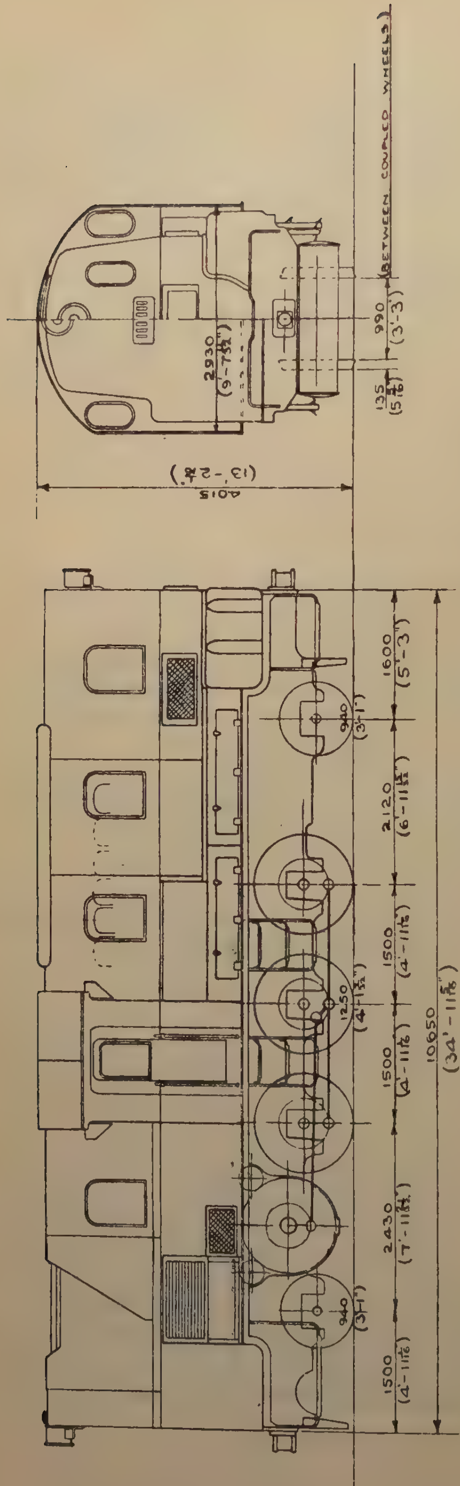


Fig. 3. — Diesel-electric locomotive, Japanese Government Railways.

of a jack shaft and driving it at opposite ends through toothed gearing and a flexible drive. The jack shaft is connected to the driving wheels by outside rods.

The coolers for the Diesel engine are independently driven by an electric motor, as also the fan for ventilation of the traction motors.

The driving wheels are 1 250 mm. (4 ft. 1 7/32 in.) diameter and the truck wheels 940 mm. (3 ft. 1 in.). The automatic continuous air brake fitted can also be applied directly. The air is obtained from the supply of air for starting purposes through a reducing valve.

The cab is of the box type and made as wide as possible within the loading gauge. The driver's compartment has dual controls on right and left hand sides, for convenience in shunting. Lighting of the cab is provided, the supply being taken from accumulators charged by the exciter current.

The locomotive is required to start a train of 500 tons excluding the engine on a gradient of 1 in 333 (3 per thousand) and to attain thereon a speed of 25 km. (15 1/2 miles) per hour. It is also required to maintain a speed of 6 km. (3 3/4 miles) per hour on a gradient of 1 in 59 (17 per thousand), 260 m. (283 yards) long, with the same load; and to attain a speed of 60 km. (37 miles) per hour when running light.

The minimum curves to be traversed are 90 m. (4 1/2 chains) radius, laid 18 mm. (11/16") wide to gauge (3 ft. 6 11/16 in.).

The Southern Railway (England) has had in service for a short time one internal combustion rail car (Drewry type) intended for light service on branch lines. This is a four-wheeled vehicle weighing approximately 8 tons and capable of seating 25 passengers and car-

rying a small amount of luggage. A petrol engine of 45 to 50 B. H. P. is situated at one end of the car, and the power is transmitted to the axle through a chain drive. Gears giving three speeds of 6, 12 and 25 miles per hour on the level are provided for each direction. There is a driving compartment with controls at each end of the car, and a hand brake is fitted. This vehicle has not been sufficiently long in service to report results.

The New South Wales Government Railways also report the use of internal combustion rail cars. No details are given.

The London & North Eastern Railway (England) have one petrol car and one petrol-electric car in service, but no details of construction or performances have been supplied.

The North Western Railway (India) are considering putting into service two Diesel-electric locomotives and two Beardmore-Diesel rail coaches, but no details of these were available for this report.

c) The London & North Eastern Railway (England) is building for trial a locomotive having a water-tube boiler and designed for a working pressure of 450 lb. per square inch, but no further particulars are available.

Locomotives of new types.

Summary of replies received.

NAME OF ADMINISTRATION.	*Turbine locomotive and steam reciprocating engines which are not directly connected to the coupled wheels.*	*Internal combustion locomotives.*	*Locomotives having boilers of special design.*
Great Western Railway (Gt. Bn.)	None.	None.	None.
London, Midland & Scottish Railway	Ljungström turbine locomotive tried on behalf of Messrs. Beyer, Peacock & Co., Manchester.	None.	None.
London & North Eastern Railway	55 steam rail cars and 1 « Sentinel » locomotive in use.	One Diesel-electric locomotive of 1 000 B. H. P. being prepared.	Locomotive with water tube boiler of 450 lb. per sq. inch pressure contemplated.
Southern Railway (Gt. Bn.)	None.	None.	None.
Great Northern Railway (Ireland)	None.	None.	None.
Metropolitan Railway (London)	None.	None.	None.
London Midland & Scottish (Northern Counties Committee).	« Sentinel » locomotive in use.	None.	None.
Gold Coast Government Railways	None.	None.	None.
Kenya & Uganda Railway	None.	None.	None.
Nigerian Railway	One « Sentinel-Cammell » coach on order.	None.	None.
South African Railways and Harbours	None.	None.	None.
Sudan Government Railways	None.	None.	None.
New South Wales Government Railways	None.	Internal combustion rail cars in use.	None.
New Zealand Government Railways	None.	None.	None.

NAME OF ADMINISTRATION.	*Turbine locomotive and steam reciprocating engines which are not directly connected to the coupled wheels.*	*Internal combustion locomotives.*	*Locomotives having boilers of special design.*
Canadian National Railways	None.	None.	None.
Ceylon Government Railways	None.	None.	None.
Bengal Nagpur Railway	None.	None.	None.
Bengal and North Western Railway	None.	None.	None.
Bombay, Baroda and Central India Railway	None.	None.	None.
Burma Railway	None.	None.	None.
Eastern Bengal Railway	None.	None.	None.
East Indian Railway	None.	None.	None.
Great Indian Peninsula Railway	Three « Sentinel-Cammell » coaches in use.	None.	None.
Madras & Southern Mahratta Railway	None.	None.	None.
North Western Railway (India)	« Sentinel » steam coaches and one « Sentinel » locomotive in use.	Two Diesel-electric locomotives and two Beardmore Diesel coaches in prospect.	None.
Rohilkund & Kumaon Railway (India)	None.	None.	None.
South Indian Railway	None.	None.	None.
Federated Malay States Railways	Steam rail cars on order.	None.	None.
Egyptian State Railways	None.	None.	None.
Japanese Government Railway	None.	One Diesel-locomotive and one Diesel-electric locomotive on order.	None.
Government of Chosen Railway	None.	None.	None.
South Manchuria Railway	None.	None.	None.

[621 .134]

REPORT No. 1

(France, Italy, Portugal, Spain and their Colonies),

ON THE QUESTION OF IMPROVEMENTS IN THE STEAM LOCOMOTIVE (SUBJECT VI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By A. PARMANTIER,

ASSISTANT CHIEF MECHANICAL ENGINEER, PARIS, LYONS AND MEDITERRANEAN RAILWAY.

Figs. 1 to 37, pp. 1581 to 1634.

SUMMARY.

(1) This question runs as follows : « Improvements in the steam locomotive. Increased pressures and higher superheats. Improvements in the design of superheaters and parts connected with superheating. Feed water heating and air preheating. Improvements of valve gears. »

(2) Translated from the French.

B. — The best arrangement of superheaters and of the parts the working of which is connected with the application of superheating.

CHAPTER III.

Feed water heating.

A. — Feed water heating by exhaust steam.

CHAPTER IV.

Air preheating.

CHAPTER V.

Valve motion.

A. — Improvement in the present types of valve motion.

B. — Special designs of motions.

CHAPTER VI.

Draft and exhaust.

CHAPTER VII.

Miscellaneous questions.

APPENDICES I TO VII.

FOREWORD.

The question submitted for discussion at the Congress and which deals with the « Improvements of the steam piston locomotive *of the usual type* » should in principle be limited to the following four points :

— Increase of the boiler pressure and of the degree of superheat.
— Improved layout of the superheaters and of those parts connected with the application of superheaters.
— Preheating of water and air.
— Improvement of the valve gear.

The reporters have however considered that the field of discussion should be enlarged so as to incorporate :

— on the one hand, those other improvements which have as their object the definite increase in the thermal efficiency of the boiler and of the motor; improvement of the exhaust, compounding, etc...
— on the other hand, certain questions much in evidence at the present time, such as the use of boosters, special steels, etc....

They have consequently been led to divide the subject in the following manner:

I. — Increase in boiler pressure.

II. — Superheating of the steam :

A. — Increase in the degree of superheat.
B. — Improvements in the design of superheaters and the parts the working of which is connected with the application of superheating.

III. — Feed water heating.

IV. — Air preheating.

V. — Valve motion.

VI. — Draft and exhaust.

VII. — Miscellaneous :

A. — Compounding (present position).

B. — Improvements in combustion.

C. — Devices for improving the circulation of water in present day boilers.

D. — Regulators.

E. — Steam driers on superheated locomotives.

F. — Soot blowers.

G. — Boosters.

H. — Use of special steels.

I. — Use of special light alloys.

J. — Lighting of locomotives.

K. — Flange lubrication.

L. — Locomotive balancing.

Appendix I gives the questionnaire drawn up in accordance with the above, as sent out to the Railway Companies.

Appendix II gives the names of the Railways who have sent in replies.

CHAPTER I.

Increased boiler Pressure.

Increased pressure may be obtained :

— either with boilers of the usual type,

— or with new types of boilers.

The first of these two divisions will be considered alone, locomotives of new types being dealt with under question V.

I. — Boiler pressure in general use when the latest superheated locomotives were built.

In the countries given in appendix II this pressure is :

— 12 to 14 kgr. per cm² (170.67 to 199.12 lb. per sq. inch) for *simple expansion locomotives.*

— 14 to 16 kgr. per cm² (199.12 to 227.56 lb. per sq. inch) for *compound locomotives.*

In the other countries, pressures exceeding 16 kgr./cm² (227.56 lb. per square inch) are found. In England the *Great Western Railway* and the *London Midland & Scottish Railway* have recently put into service 4-6-0 *simple expansion* superheated locomotives with boilers having a working pressure of 250 lb. per square inch, that is to say 17.58 kgr. per cm² (1).

II. — Intentions of the Railways as regards increasing the boiler pressure.

a) *French Est Railway.*

The Company intends to increase the pressure above that in use up to the present.

With this object, the boiler of a *compound* superheated express locomotive of the 4-6-0 type has been built for a working pressure of *20 kgr. per cm²* (284.46 lb. per sq. inch) instead of 16 kgr. (227.56 lb. per sq. inch). The engine which has been in service since April 1926 has given no trouble. The *French Est* intends to carry out some comparative tests with it on the Czeczott method by running it in turn at 16 kgr. per cm² and 20 kgr. per cm² pressure.

Although the test is still too short for any conclusion to be drawn, the Company is of opinion that provided the boiler is very carefully built and without any alteration in the principle of design, the increase of the pressure to 20 kgr. per cm² can be considered without apprehension. It appreciably increases the available power for short periods of « collar work ».

b) *French Nord Railway.*

The Company is considering the construction of superheated *simple expansion* suburban locomotives with normal boiler pressure of 12 kgr. per cm² (170.67 lb. per sq. inch) but designed so that, if desired, the pressure can be raised to 14 and even to *16* kgr. per cm² (119.12 and 227.56 lb. per sq. inch).

c) *Paris, Lyons & Mediterranean Railway.*

The Company has under consideration the test of *compound* and *superheated* 4-6-2 and 4-8-2 locomotives with boilers working at 20 kgr./cm² (284.46 lb. per sq. inch).

(1) The weight on the three coupled pairs of wheels of these locomotives is 68.5 tons on the Great Western Railway, and 63.5 tons on the London Midland & Scottish Railway or more than 20 tons per axle. (See the *Railway Engineer* of July 1927 and January 1928, and the *Railway Gazette* of July and August 1927.)

d) *Italian State Railways.*

Dynamometer car trials with two superheated simple expansion locomotives of group 685 (1), one with a boiler pressure of 12 kgr. per cm² (170.67 lb. per sq. inch) and the other of 16 kgr. per cm² (227.56 lb. per sq. inch) have shown that the second used 5 % less coal than the first.

Furthermore, the locomotives of group 685 which are modified group 680 locomotives (2) retaining the boiler pressure of 16 kgr. per cm² have been able to haul a 5 % greater load than the other locomotives of group 685 with a boiler pressure of 12 kgr. per cm².

In view of these results, the *Italian State Railways* propose to raise the pressure from 12 to 14 and even *16* kgr. per cm² of 1 200 *simple expansion* locomotives.

To sum up, there is a very definite movement towards an increase in the boiler pressure now used, but not beyond the limit of 20 kgr. per cm² (284.46 lb. per sq. inch).

III. — Use of special steels in boiler work.

On many railways, one of the most serious obstacles in the way of increasing the power by raising the boiler pressure is the increase in weight which results. This increase in weight could none the less be reduced appreciably if it were possible to make use of lighter materials all other factors being equal. In this field, attention may be called to the use on the Canadian Pacific Railway of special steels with 3 % nickel for boiler plates, whereby it has been possible to raise the pressure from 14 to 17.5 kgr. per cm² (199.12 to 242.50 lb. per sq. inch) without increasing the thickness of the plates (1).

(1) The locomotive of group 685 are superheated simple expansion 4-cylinder 2-6-2 engines.

(2) The locomotives of group 680 are 2-6-2 saturated steam compound engines with four cylinders placed unsymmetrically.

IV. — Conclusions.

a) It appears that the pressure can be increased from 16 kgr. per cm² up to 20 kgr. per cm² (227.56 to 284.46 lb. per sq. inch) without difficulty;

b) The use of special steels in the construction of boilers is to be kept in view;

c) The increase in boiler pressure is equally valuable in the case of simple expansion as for compound locomotives.

CHAPTER II.

Superheating.

A. — Increased superheat.

I. — Lines of investigations. Tests carried out and results obtained.

The improvement of the superheat of locomotives has been investigated with particular care by the French railways during recent years.

a) *Tests carried out with a view to obtaining a higher superheat with a given type of superheater.*

The Alsace-Lorraine, the State, and the Paris, Lyons & Mediterranean (2) Railway Companies have carried out methodically tests on the following basis:

(1) See *Railway Mechanical Engineer*, April 1927 : Locomotive boilers with nickel steel plates.

(2) For the tests carried out on the Paris, Lyons & Mediterranean Railway, see the detailed article in the June 1929 number of the *Revue Générale des chemins de fer*, by Mr. Ch. Bourrié.

to circulate a large proportion of the hot combustion gases round the superheater element or, which comes to the same thing, reduce the ratio $\frac{R_s}{R_b}$ of the resistance R_s to the passage of the gases through the nest of flue tubes and of R_b through the boiler tubes (1).

In order to lower the ratio $\frac{R_s}{R_b}$ several alterations have been considered, such as:

— reduction of the diameter of the superheater elements,

— alteration of the supports and stays of the superheater elements so as to reduce the space occupied by them,

— use of ferrules in the boiler tubes (2),

— increase in the diameter of the flue tubes.

The superheat has also been increased by bringing the rear loops of the superheater elements nearer the fire box tube plate.

Figures 1 and 2 illustrate the supports and stays used by the *French Nord* Railway, and by the *Paris, Lyons & Mediterranean* Railway; figure 3 shows the arrangement « en chicane » used by the *Alsace-Lorraine,* and the *Paris-Orleans* and under test on the *Paris, Lyons & Mediterranean* (1) Railways : a very similar arrangement is used by the *French Est* Railway to carry and keep in place the DM elements used by it.

The table (Appendix III) gives a summary of the results obtaind during some of the many tests on superheating carried out by the French railways (2). The table has been completed by including in it the results of the tests on the *Belgian State* Railways, tests which were carried out on identical lines to those followed in France (3).

The table also gives the following characteristic ratios :

$$\frac{C}{G} \text{ or } \frac{\text{Total heating surface.}}{\text{Grate area.}}$$

---

(1) We shall describe as :

— *flue tubes* (or nest of superheater flue tubes) the smoke tubes (or nest of smoke tubes) containing the superheater elements,

— *boiler tubes* (or nest of boiler tubes) the smoke tubes (or nest of smoke tubes) not containing superheater elements.

(2) The fitting of ferrules in the boiler tubes is done as a temporary measure whilst waiting for the renewal of the fire box tube plates : when this is done, the plate will be drilled out to the proper diameter. The *Paris, Lyons & Mediterranean* Railway began by using steel ferrules driven into the boiler tubes, but it was soon seen that some other method was needed (copper bushes between the tube plates and the tubes) owing to « bird nests » forming.

(1) In order to avoid any trouble through the two side by side tubes of a superheater element being rigidly connected, the stays are now only welded to one of the tubes, the other being held by surface contact alone.

(2) Cf. *Bulletin of the International Railway Congress Association*, August 1926. Results of tests on a four-cylinder 4-6-2 locomotive, class 10, of the *Belgian State*, by F. Legein.

(3) To determine the resistance of the tubes we have used the formula $R = \alpha \frac{lc}{s^3}$ generally accepted for straight tubes (α being a coefficient, l, c and s being respectively the length, perimeter, and section of the tube).

As it is moreover solely a question of relative values, we have arbitrarily taken the coefficient α as equal to 1 which gives $R = \frac{lc}{s^3}$.

$\frac{\Sigma}{G}$ or $\frac{\text{Superheating surface.}}{\text{Grate area.}}$

$\frac{\Sigma}{C}$ or $\frac{\text{Superheating surface.}}{\text{Total heating surface.}}$

$\frac{Q}{G}$ or $\frac{\text{Area of steam passage in the superheater elements.}}{\text{Grate area.}}$

$\frac{R_s}{R_b}$ or $\frac{\text{Resistance to the passage of the gases due to the superheater flues.}}{\text{Resistance to the passage of the gases due to the boiler tubes.}}$

$\frac{S_s}{S_b}$ or $\frac{\text{Sectional area of the gas passage through the superheater flues.}}{\text{Sectional area of the gas passage through the boiler tubes.}}$

If table III be examined, it will be seen that good results have been obtained with superheaters having large tubes by giving the above characteristic ratios values in the neighbourhood of :

50 for $\frac{C}{G}$

0.35 for $\frac{\Sigma}{C}$

0.004 for $\frac{Q}{G}$

0.20 for $\frac{R_s}{R_b}$

or

1 for $\frac{S_s}{S_b}$

The test carried out in 1914 at Altoona on a Schmidt type flue tube superheater in order to ascertain the effect of the lengths of the various parts composing an element should not be overlooked.

Without going into details, tests were made in particular with elements with which the position of the front loop of the element could be altered. The conclusion was come to that, as regards superheat, the front part of the two middle branches of the elements (part marked *a b c* on figure 4) could be suppressed, a result which is quite natural in view of the relative temperature of the combustion gases and of the steam already partly superheated; this arrangement however, was not adopted by the *Pennsylvania Railroad*, as in practice it was found that it resulted in the tubes being blocked by ashes at the point where the middle branches stopped (1).

This latter drawback should disappear if when the part *abc* of the superheater element is suppressed, a feed water heater element is arranged in the place liberated (fig. 5); the combustion gases can in this

(1) Cf. *Revue Générale des chemins de fer* of January and February 1923, « Experimental investigation of the locomotive boiler », by P. Conte.

In addition, attention is called to the experiment made by the *Belgian State Railways* with a superheater, the forward loop of which ends 1.40 m. (55 1/8 inches) from the smoke box tube plate. (*Bulletin of Railway Congress*, August 1926.) (*Op. cit.*).

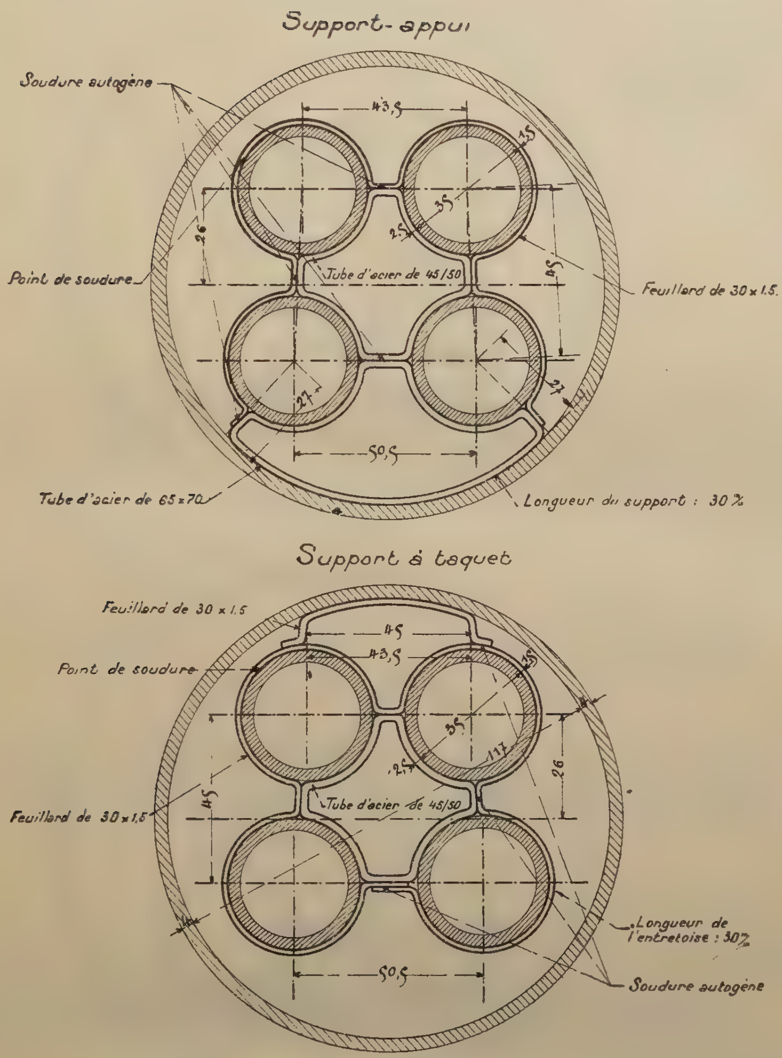


Fig. 1. — Superheater element supports *(French Nord).*

Explanation of French terms :

Feuillard = Strip. — Longueur de l'entretoise = Length of stay. — Longueur du support = Length of support. — Point de soudure = Spot weld. — Soudure autogène = Autogenous weld. — Support-appui = Carrier support. – Support à taquet = Suspended carrier. — Tube d'acier = Steel tube.

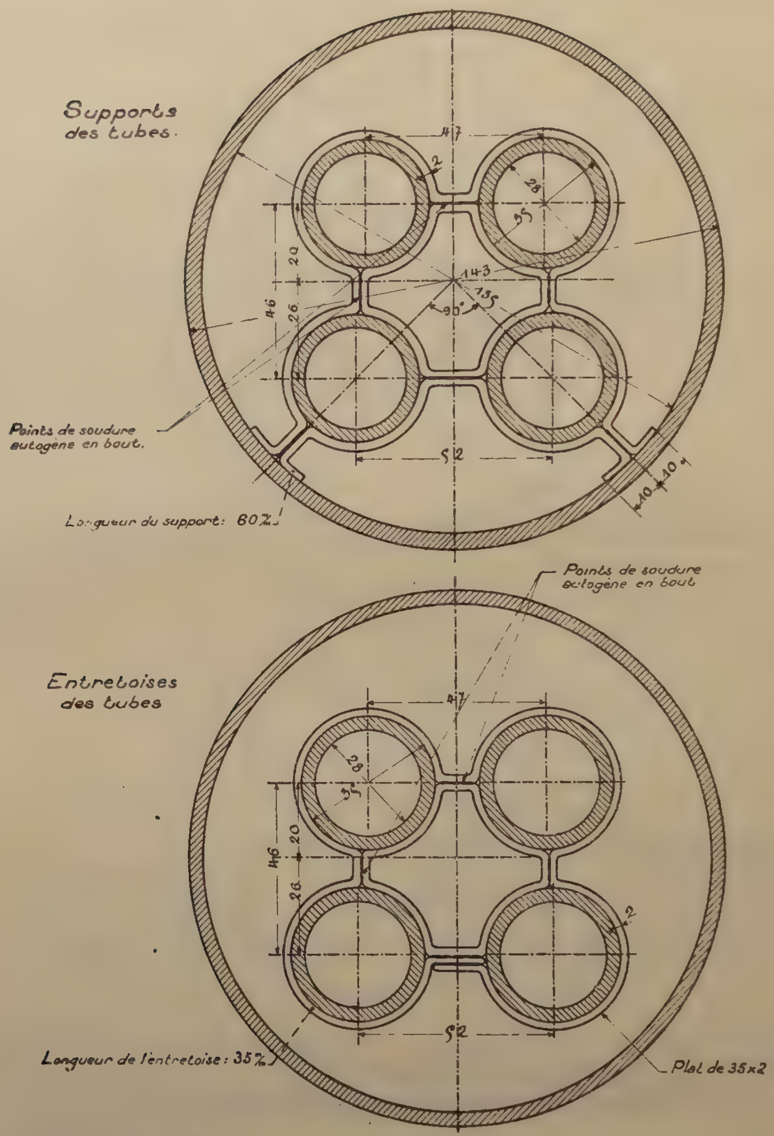


Fig. 2. — Superheater element support and stays *(Paris, Lyons & Mediterranean).*

Explanation of French terms :

Entretoises des tubes = Tube stays. — Longueur de l'entretoise = Length of stay. — Longueur du support = Length of support. — Plat de ..... = Flat bar of..... — Points de soudure autogène en bout = Spot welds on ends. — Support des tubes = Element carriers.

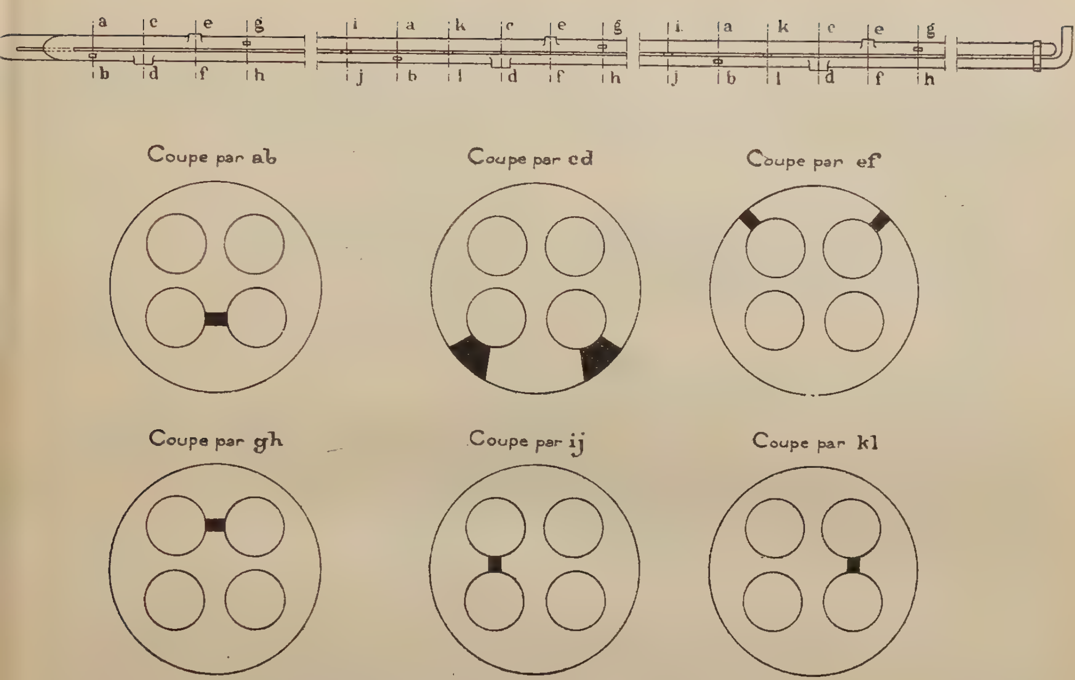


Fig. 3. — Element carriers (*Paris-Orléans Railway*).

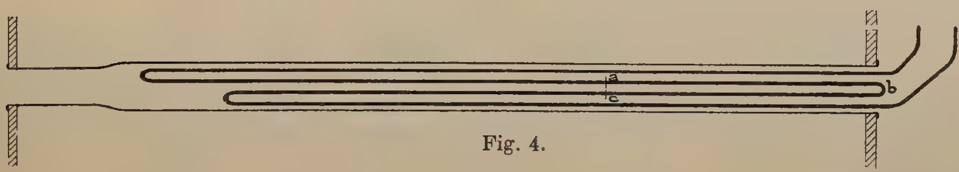


Fig. 4.

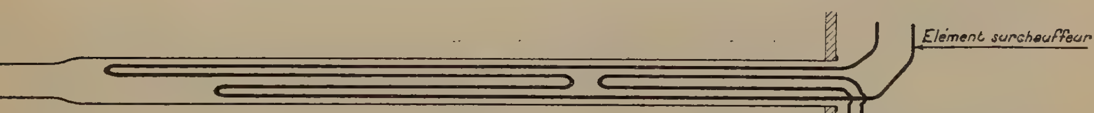


Fig. 5.

Explanation of French terms in figs. 3 and 5 :

Coupe = Section. — Élément surchauffeur = Superheater element. — Élément réchauffeur = Feed water heating element.

way be made to yield up a certain number of heat units to the feed water instead of abstracting them from the already superheated steam. This fact forms the basis of the Dabeg Economiser with dual elements mentioned in chapter III.

b) *Tests carried out in order to improve the superheat by altering the type of superheater element.*

A superheater element, as the *Est* railway points out, should satisfy the following conditions :

— permit the steam to circulate in a rational manner, *i. e.* in the opposite direction to that of the combustion gases in the part where it should become superheated,

— be so designed that this part of the element has the largest possible surface in contact with the gases,

— return the steam when superheated to the header by a tube offering little surface in contact with the combustion gases,

— offer the least possible resistance to the flow of the combustion gases,

— reduce to a minimum losses of pressure of the steam circulating in the element.

The *Est Company* has endeavoured to satisfy these conditions in the *DM element* by making the saturated steam pass through four flattened tubes and returning the superheater steam through a large circular tube (fig. 6).

The substitution of the DM elements for Schmidt elements on the express 4-6-0 locomotive (3200) has resulted in a substantial increase in the superheat temperature, which usually exceeds 350° C. (662° F.) and has at the same time given an appreciable saving of fuel.

The *Est* now fits the DM elments to all new locomotives and in addition, to locomotives not already fitted whilst undergoing repairs.

The *Paris, Lyons & Mediterranean Railway* made comparative tests of the DM and Schmidt elements, but found no marked superiority of the former over the latter.

Another type of superheater element has been investigated by the *French State* and *Paris-Orleans* Railways, namely the *Houlet* shown in figure 7 and which consists of a tube having an annular cross section with a return tube of circular section running through the center.

The preliminary tests carried out on the *French State* appear to show that this pattern of element should give good results.

c) *Tests carried out with the object of improving the superheat by altering the type of header.*

The design of the usual pattern Schmidt header with the saturated and superheated steam pockets separated by a wall in the casting is undoubtedly far from perfect from a theoritical point of view, and it was reasonable to expect that tests of headers with separate chambers would be made.

The *Est* Company has made such a test on 10 locomotives, the results obtained when compared with those given by the other engines were not however conclusive.

II. — Limit of the superheat temperature.

The tests made by the French railways and summarised above have shown that it is possible to obtain easily, superheat temperatures of the order of 380° C. (714° F.) and even in certain cases 400° C. (752° F.).

The temperature of 350° C. (662° F.) considered until recently as the maximum, is now considerably exceeded.

What should be the superheat temperature to be aimed at on the locomotives?

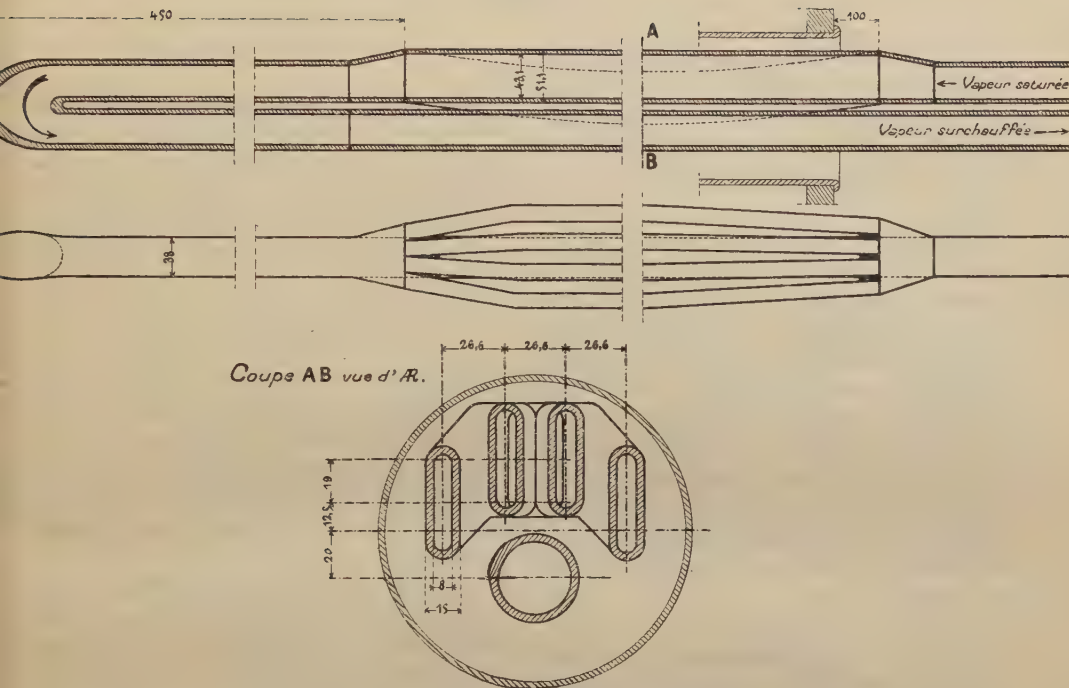


Fig. 6. — DM superheater element.

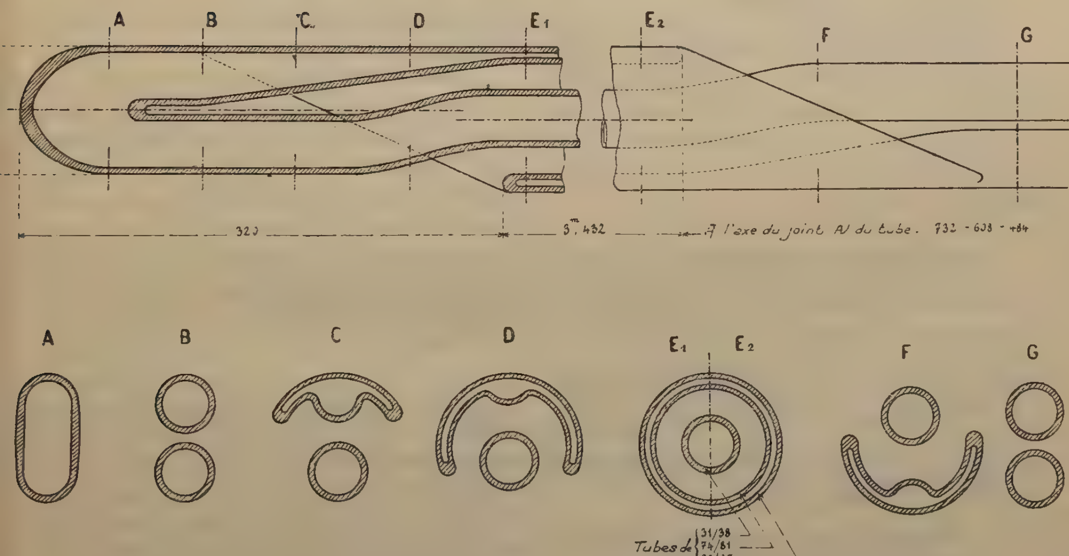


Fig. 7. — Houlet superheater element.

Explanation of French terms in figs. 6 and 7 :

A l'axe du joint AV du tube = To the centre line of the forward joint of the tube. — Coupe AB vue d'AR = Section trough AB from behind. — Vapeur saturée = Saturated steam. — Vapeur surchauffée = Superheated steam.

It should be the highest possible evidently, on condition first of all of not reducing the efficiency of the locomotive, and subsequently of not causing any trouble as regards lubrication, packing and viscosity.

The different companies consulted on the subject, generally agree that at the present time 400° C. (752° F) may be taken as the maximum. The *Paris-Orleans* Railway, however, considers, and it would seem with reason, that this maximum should only apply to compound locomotives, and that 350° C. (662° F.) should be the limit for simple expansion locomotives; it appears in fact desirable if the efficiency is not to be reduced that there should not be too much superheat left in the exhaust.

B. — The best arrangement of superheaters and of the parts the working of which is connected with the application of superheating.

This question was dealt with in great detail at the 9th Session of the Congress (Rome 1922). See on this subject the following numbers of the *Bulletin of the International Railway Congress Association* :

Preliminary documents :

1st report by Mr. Lacoin (Bulletin of September 1921, page 1157);

2nd report by Mr. Churchward (Bulletin of October 1921, page 1527).

Special reporter : Mr. Lacoin (Bulletin of April 1922, page 653).

Report of the discussion at the Congress and final summary :

Bulletin of April 1923, page 292.

I. — Superheaters.

As regards the superheater, the question here is one of providing a design which will be more satisfactory in service, more simple in construction or easier to maintain, and not of getting a higher superheat (this point is dealt with in paragraph A).

a) *Type of superheater.*

The type of superheater which is still generally preferred by the railways, is the *Schmidt superheater with large flue tubes* (1). Compared with the Schmidt superheater using small tubes it is in fact, cheaper, easier to maintain, and simpler in design.

The *Smyrna to Cassaba* Railway, however, prefer the type E superheater with small tubes of the Superheater Corporation (2) which has given them entire satisfaction : this type of superheater is also fitted to a certain number of locomotives belonging to the *Algerian State Railways.*

The *Central Aragon* Railway uses on its 4-8-0 locomotives a flue tube superheater of the Flamme type with double loop elements, and completely separate saturated and superheated steam headers: each header is formed of a horizontal drum and of three vertical collectors in line with the center lines of two vertical

(1) The *Est* Company has adopted the superheater with large flues but with *DM elements.*

(2) Cf. *Locomotive Cyclopedia of American Practice,* 1927 edition, page 296 et seq. According to the Superheater Corporation, the principal advantage of the « E » type superheater over the flue tube superheater is that a much greater evaporative surface (10 to 12 %) can be obtained. But can an equally high superheat temperature be obtained with it ?

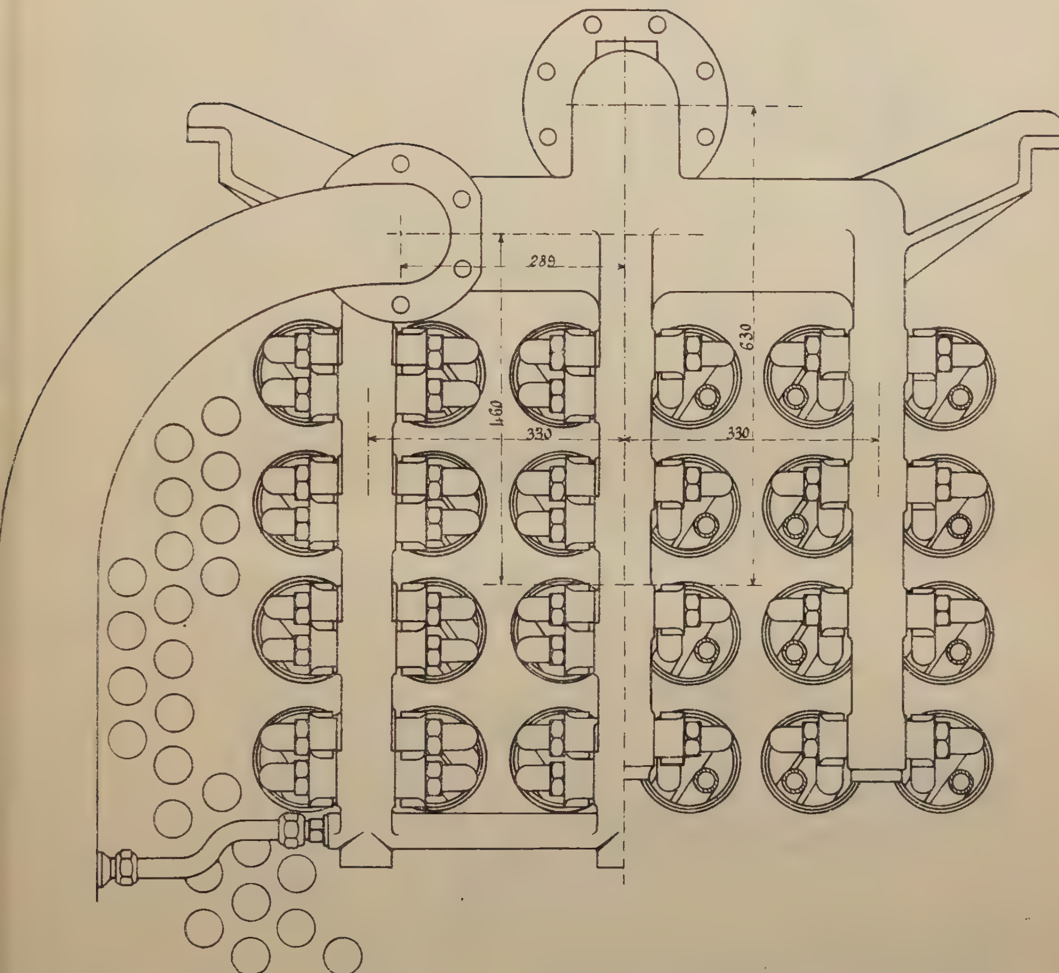


Fig. 8. — Superheater with separate headers, Flamme type, of the *Central Aragon Railway.*

lines of tubes, the elements terminating on each side of the vertical collectors (figs. 8 and 9).

b) *Back loops of the superheater elements.*

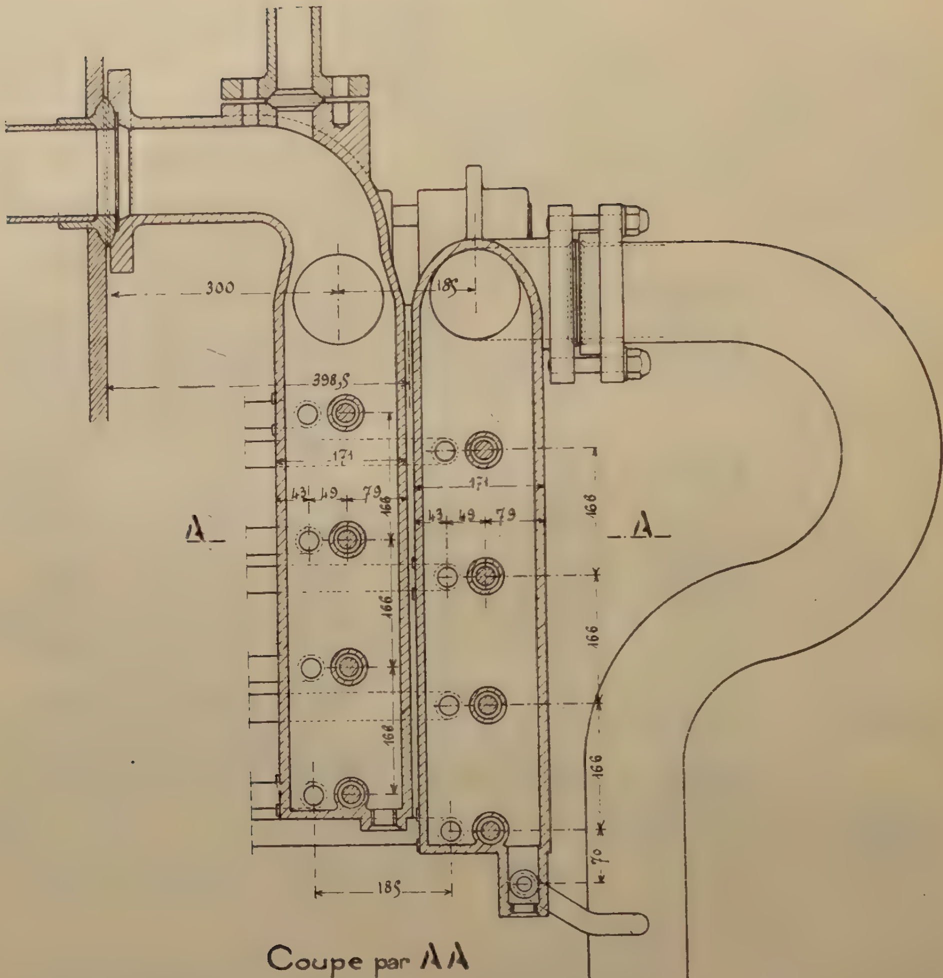
The distance from the firebox tube plate to the back loops varies between 600 mm. (23 5/8 inches) and 200 mm. (7 7/8 inches); as a rule these are 450 mm. (17 11/16 inches).

The ends are generally forged. Figures 10, 11 and 12 show the methods of manufacture of the ends used by the *French Nord*, and the *Paris, Lyons & Mediterranean Railways*, and the Superheater Corporation.

c) *Method of connecting the elements to the headers.*

The joint is made either with :

— flat faces with copper asbestos joint washers, or with



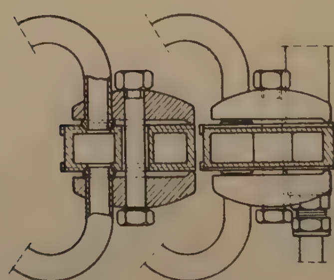


Fig. 9. — Superheater with separate headers, Flamme type, of the *Central Aragon Railway.*

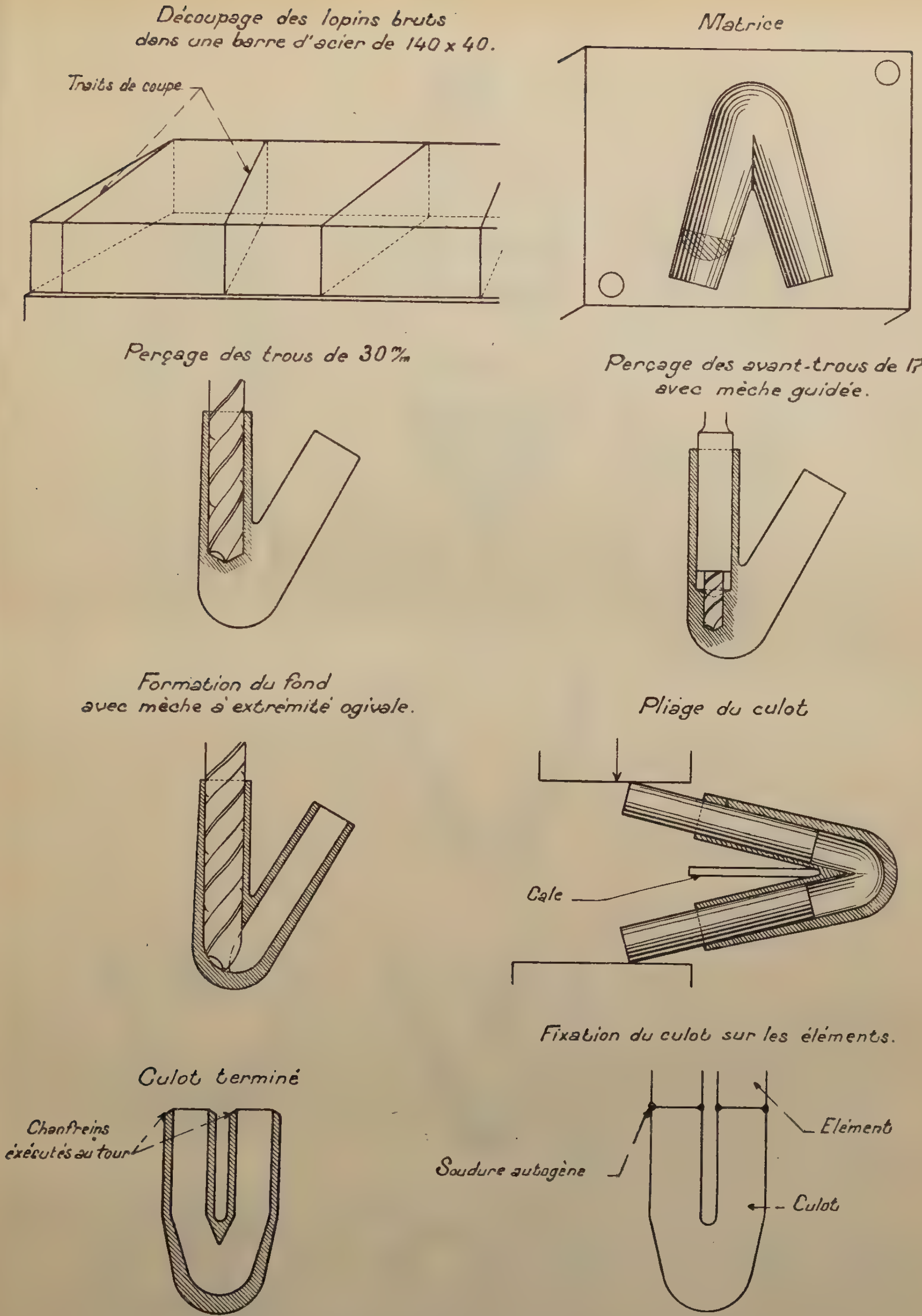


Fig. 10. — Method of making spear ends used on the *French Nord Railway*.

Explanation of French terms : Cale = distance piece. — Chanfreins exécutés au tour = Chamfer done in the lathe. — Culot = End. — Culot terminé = Finished end. — Découpage des lopins bruts dans une barre d'acier de ..... = Parting the blanks from a 5 1/2 × 1 9/16 inches steel bar. — Élément = Element. — Fixation du culot sur les éléments = Fastening end to the elements. — Formation du fond ..... = Finishing bottom with ogival ended drill. — Matrice = Die. — Perçage des avant-trous de ..... Drilling small leading holes with guided drill. — Perçage des trous de 30 mm. = Drilling the 1 3/16-inch holes. — Pliage du culot = Bending elbow. — Soudure autogène = Autogenous weld. — Traits de coupe = Lines along which bar is parted.

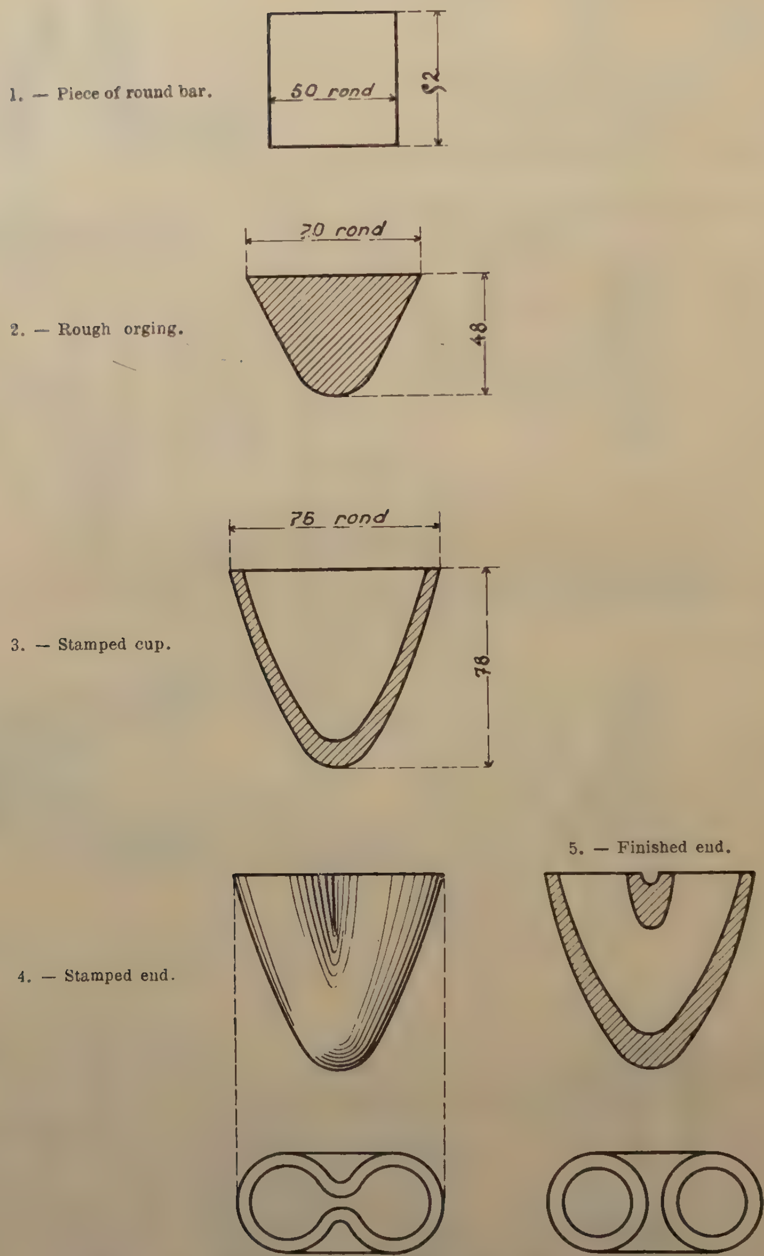


Fig. 11. — Method of making element spear ends in use on the *Paris, Lyons & Mediterranean Railway.*

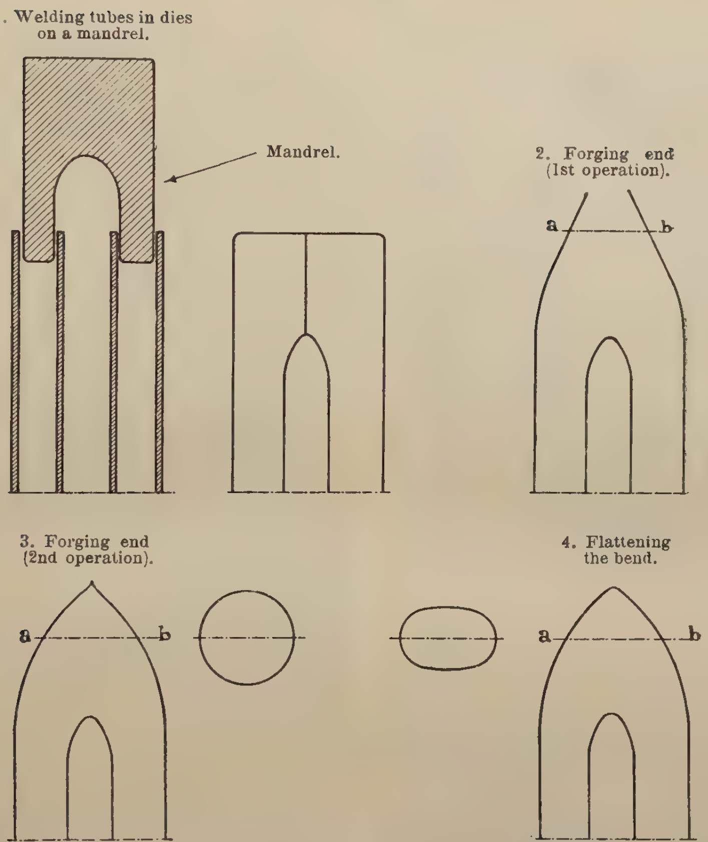


Fig. 12. — Superheater Corporation's method of making spear ends.

— spherical seats without any jointing material.

Figure 13 shows the type of spherical seat adopted by the *French Est.*

d) *Superheater dampers.*

As a general rule, dampers have been suppressed and have not been replaced by any similar arrangement (1).

The following devices have given good results as regard the life of the elements :

— *the Robinson draft reductors* which automatically blow a jet of steam backwards against the flow of the combustion gases through the flues when the blower is in use (locomotives 140-171 and 270 of the *French State* Railways).

Snifting valves fitted on the saturated side of the heater (2) by means of which

(1) The *Tunisian Railways* have retained the dampers on goods engines working over hilly sections.

(2) See below the paragraph dealing with the air admission valves.

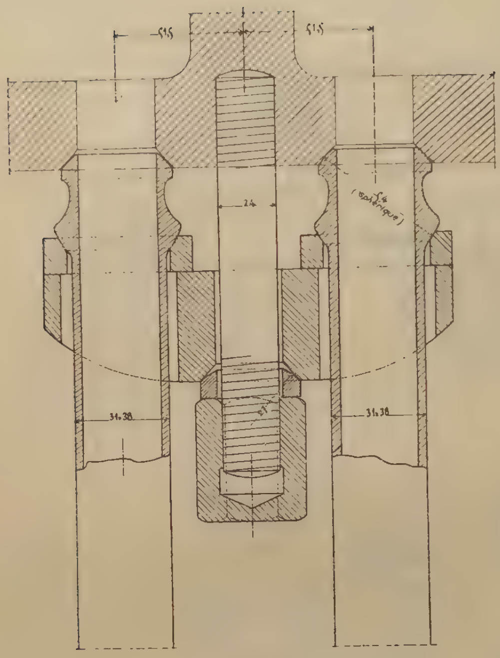


Fig. 13. — Spherical joints for fastening the elements to the headers *(French Est Railway)*.

air is drawn in when running with the regulator closed, and cools the elements and at the same time becomes heated.

e) Instructions given to drivers as regards running with closed regulator.

When such instructions are issued, they require a small quantity of steam to be supplied to the cylinders (*Est, French State*, and *Paris, Lyons & Mediterranean Railways*). The *Paris-Orleans* requires its drivers to open the water injection valve slightly before closing the regulator and not to shut off this valve again until after having reopened the regulator.

II. — Pyrometers.

Many railways (1) have all their locomotives fitted still with pyrometers: there is a tendency on several (2) to suppress this fitting. As a matter of fact it appears to be difficult to find a good pyrometer whether of the saturated steam tension, thermo-electric or mercury type for locomotive use. It seems moreover, and this is practically the general opinion — that a knowledge of the temperature of the superheated steam is unnecessary for the ordinary working of the locomotive.

The search for satisfactory pyrometers — if only for use when making trials — is still being made by the railways; experiments are now being made with the thermo-electric Kayser and Schmidt, and Chauvin and Arnoux pyrometers (on the *Est*) the mercury pyrometers Richard, and the Soupire on the *Paris-Orleans* and *Est* Railways respectively.

III. — Lubrication of valves and pistons.

a) Superheater cylinder oils.

The table Appendix IV gives the specification of the superheater oils used by some of the Companies whose names are given in the list of appendix II.

As regards the results obtained, the railways state that as a general rule, they are satisfied with the oils used. The *Alsace-Lorraine*, the *French Nord* and the

(1) *Aragon, Andalusian, North of Spain, French Est, French Nord, Algerian State, Tunisian, Damas-Hamah, Smyrna to Cassaba* and *Italian Mediterranean* Railways.

(2) The *French Est* Railway has decided to suppress the use of pyrometers and the *French Nord* Railway is considering the same policy on its goods engines.

Paris, Lyons & Mediterranean Railways have however found that with high superheat (400° C. = 752° F.) carbon deposits are formed in the cylinders.

b) *Lubricators and non-return valves.*

Displacement and mechanical lubricators divide the favour of the Companies. The table appendix V shows however that there is some slight preference for the mechanical lubricators.

Are the latter better than displacement lubricators in spite of their higher first cost and more expensive maintenance ?

Various Companies have answered the question in the affirmative as the result of tests, the most thorough of which being those carried out by the *Italian State Railways* [1]. It was found that in actual fact, the displacement lubricators were quite irregular as regards feed and ceased to supply oil as soon as the steam pressure in the parts to be lubricated exceeded a certain value.

The *French Est* Railway, has on the other hand, shown that it was perfectly well possible to obtain with displacement lubricators almost as satisfactory lubrication as with mechanical lubricators, provided that properly designed non return valves were used. In view of the results obtained, we think it will be of value to reproduce below the most important passages of the report made by the *Est* Railway on this subject :

The trials suggested by the tests made by the *Italian State Railways* were carried out on a 4-6-0 compound superheated locomotive with a boiler pressure of 20 kgr. per cm² (284.46 lb. per square inch).

. . . .

I. — **Results obtained with lubricators of the ordinary patterns.**

A. — *Displacement lubricators.*

The lubricator used was of an ordinary 4-feed pattern.

The oil on leaving the lubricator passed through a 0.8 mm. (1/32 inch) hole, into the distribution pipe.

. . . .

Every time the regulator was opened there was *a blow back* towards the lubricator and the lubrication was stopped.

On the other hand each time the regulator *was shut* there coincided *an outward flow* of oil towards the cylinders or steam chests. A sort of *suction* and *partial emptying of the pipe* was produced.

It was also found that in normal working, when the speed was relatively slow and the regulator was wide open, the flow of oil *stopped for long periods.*

. . . .

The observations made showed moreover, that the control of the feed by the sight feed taps in the cab is *often* quite deceptive. Even when the oil can be seen through the glass to be flowing and even through inspection tubes placed at the back, no circulation of oil is found to be taking place in the pipes at the front end near the cylinders.

In addition, a detailed examination of the manner in which the displacement lubricator functions as well as practical tests have made it possible to show that even when one or more of the distribution pipes is blocked or closed, the oil continues to pass through the glasses, the oil flowing through the outlets re-

(1) Cf. *Rivista Tecnica delle Ferrovie Italiane* of the 15 March 1926 : « Displacement lubricators » by G. Corbellini.

maining clear or flowing back to the upper part of the lubricator in the condensation bulb.

B. — *Mechanical lubricators.*

The lubricator used had a high capacity pump with a single plunger with automatic regulator by which the pressure on the outlet side could be set (at about 30 kgr. per cm² = 427 lb. per square inch).

. . . .

« The following observations were recorded :

« On *starting* the oil is only delivered to the cylinders immediately if the pipes have been filled beforehand. Otherwise, owing to the low output of the lubricator, some time (40 to 45 minutes) can elapse before the pressure in the pipe is high enough to ensure the oil flowing.

« In *ordinary running* and *so long as the regulator is not closed,* the feed is regular and the delivery of the oil is little affected by the variations in pressure in the cylinders or steam chests, as a consequence of the high pressure in the feed pipe.

« But *if the regulator is closed,* there occurs at that moment a partial emptying of the pipe in spite of the non return spring loaded valve at its end. Owing to the time required to refill the pipe, the lubrication can be interrupted for a fairly long period. »

II. — Methods adopted after tests in order to regularise the feed of the lubricators.

A. — *Displacement lubricators.*

Very satisfactory results were obtained by making the following alterations to the displacement lubricators.

1. The valves, balls, or diaphragms first fitted to the pipes at one end or the other were removed.

2. Where the pipes ended at the cylinders or steam chests, the fitting shown in figure 14 having a hole of 1 mm. (1/64 inch) diameter protected by a sieve with about forty smaller diameter holes was used.

In this way, the supply pipe was practically relieved from the variations of steam pressure in the parts to be lubricated.

Observations showed in fact that the state of pressure in the pipe as modified, was practically independent of the variation in pressure in the cylinders and steam chests and *the quantity of oil delivered was* VERY NEARLY CONSTANT.

Under all conditions of working, speed, cut off, and regulator opening, a finely divided mixture of steam, water, and oil moving at a nearly uniform speed was observed in the inspection tubes.

This mixture is diffused at the inlet point into the cylinders as a result of passing through the strainer and the capillary orifice. Any foreign matter is prevented from passing by the sieve and falls into a special pocket provided.

B. — *Mechanical lubricators.*

. . . .

The following alterations were made with complete success :

1. A fitting as shown in figure 15 to give supply of steam through a capillary orifice with a non return valve to prevent any feed back to the boiler was mounted on each supply pipe where it left the sight feed glass [1].

2. Each oil delivery pipe was fitted with the capillary orifice and strainer described above when dealing with displacement lubricators at the point of attachment to the part to be lubricated.

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[1] The injection of steam into the lubrication pipes has been arranged in a slightly different manner (*Wakefield anti-carboniser* under test on the *Paris, Lyons & Mediterranean Railway).*

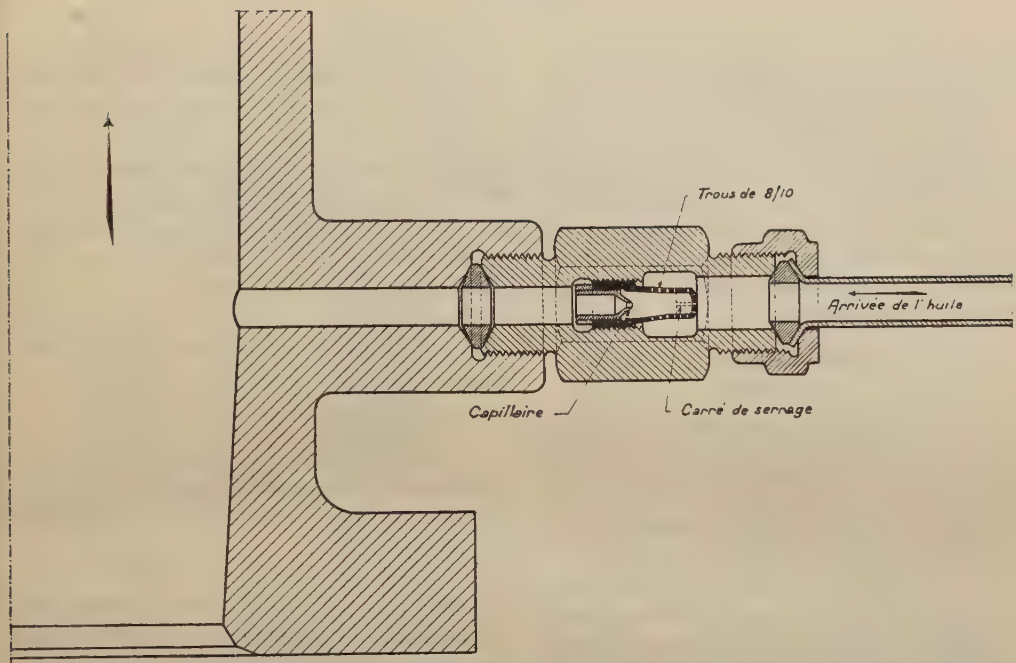

Fig. 14. — Capillary orifice with sieve arranged at the point of delivery of the oil to the steam pipe. (*French Est Railway*).

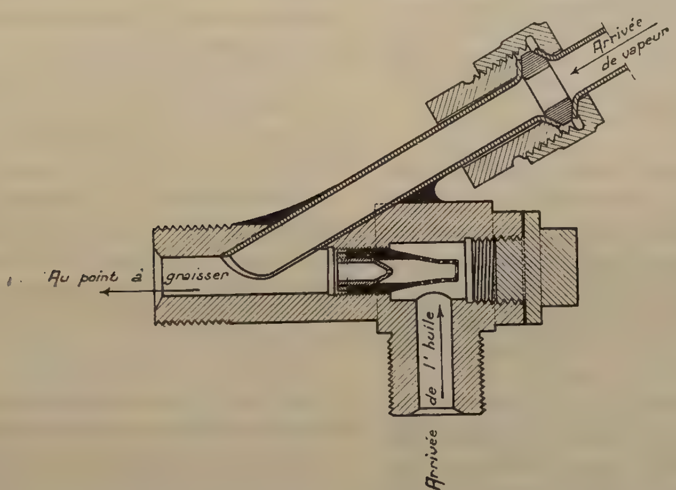

Fig. 15. — Arrangement for supplying steam in conjunction with a capillary orifice on each oil pipe. leaving the mechanical lubricator (*French Est Railway*).

Explanation of French terms in figs. 14 and 15 : Arrivée de l'huile = Oil arrival. — Arrivée de vapeur = Steam supply. — Au point à graisser = To the point to be lubricated. — Capillaire = Capillary hole. — Carré de serrago = Square for screwing home. — Trous de 8/10 = 1/32-inch holes.

This alteration was satisfactory from every point of view and the observations made shoved that the *oil was fed* QUITE REGULARLY under all running conditions.

The oil appeared through the inspection glasses to be in the form of minute globules distributed through a mixture of steam and condensed water which moved steadily forward towards the cylinders and diffused itself in the steam when it got there.

III. — Results obtained on engines in service.

The alterations described were carried out as the result of trials with mechanical and displacement lubricators on engines in service.

The results in service confirmed the observations made during the tests.

In particular, the high pressure piston rings of engines using high temperature steam frequently reaching 370° C. (698° F.) have remained in use without loss of steam tightness for mileages of 25 000 miles and even 37 500 miles whereas with the orignal design they would hardly last 6 250 miles. The consumption of oil was reduced at the same time, from 9 to 7 gr. per km. (8.17 to 6.35 drams per mile).

. . . .

The conclusion should not be drawn from the above information that the mechanical lubricator shows a marked superiority over the displacement type, but it can be stated that the *satisfactory working of a lubricator depends to a large extent upon the pattern of retaining valve adopted.*

The tests carried out on the *Reichsbahn* and described by Mr. R. P. Wagner in the 19 December 1925 number of the *Zeitschrift des Vereines deutscher Ingenieure* should also be noted.

The author begins by pointing out that displacement lubricators had to be replaced by mechanical lubricators; he then reviews the various types of pump and retaining valves tested. Then after showing that the *Reichsbahn* prefers *high pressure* pumps [1], Mr. Wagner stresses the necessity for fitting on the supply pipes where they enter the steam chest retaining valves of ample strength and perfectly tight the best types of which are the *diaphragm* and *piston patterns.*

The piston type retaining valves are now being introduced on the *Paris, Lyons & Mediterranean* Railway (fig. 16).

c) *Feeds and points of delivery.*

All possible combinations of lubrication are to be found as the following information giving the points of delivery of the oil shows :

— valves and cylinders (*Madrid to Saragossa and Alicante, North of Spain* and *French Midi Railways*),

— valves and H. P. cylinders only (*Alsace-Lorraine, Paris-Orleans, French Nord*),

— valves only (*French State* and *Paris, Lyons & Mediterranean*),

— H. P. valves and H. P. steam chests only (*French Est*) [1],

— H. P. cylinders only (*French Est*) [2].

As a rule, there is a separate feed corresponding to each outlet from the lubricator : split feeds are found however for the lubrication of the valves (*French Midi, French Est*) [3].

d) *Tests of lubricants other than oil.*

On the *French Est* Railway a trial is being carried out on the lubrication of

(1) The reservoirs of the Bosch lubricators are designed for pressures up to 300 kgr. per cm² (4 267 lb. per square inch).

(2) On high speed locomotives, or long stroke valves.

(3) On locomotives other than those of (2).

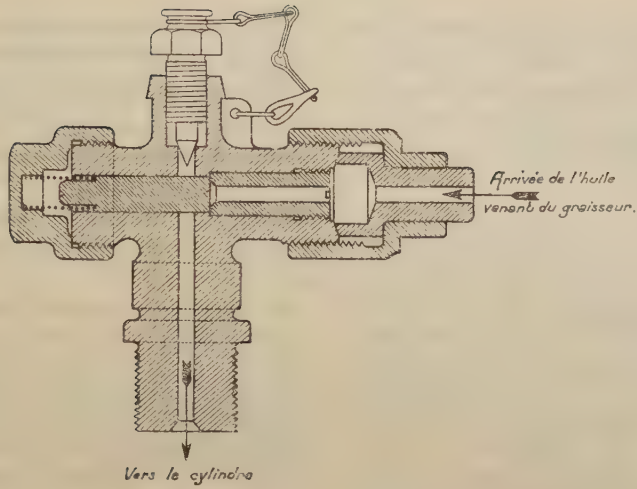

Fig. 16. — Lavezzari retaining valve.

Explanation of French terms : Arrivée de l'huile venant du graisseur = Oil supply from the lubricator.
Vers le cylindre = To the cylinder.

the cylinders and valves by means of graphite.

Lubrication by graphite, independent of the lubrication by oil will be in addition to the latter so as to reduce friction and economise the consumption of oil.

IV. — Piston valves.

Piston valves are almost exclusively used [1] but no particularly new feature has been reported. We note however :

— the use of a large number of rings (6 per piston) on the new piston valves made of steel on the *Italian State Railways* (fig. 17),

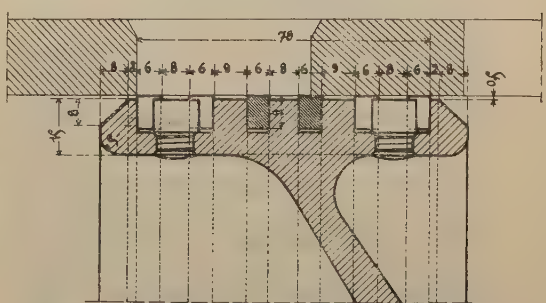

Fig. 17. — Piston valve of the *Italian State Railways*.

— the tendency to reduce the weight of the valves to the greatest possible extent so as to reduce the fatigue stresses in the motion and the vibrations due to inertia forces.

The only novelty to be found, is the *Trofinoff* piston valve (fig. 18) undergoing test by the *Midi* Company on a 4-6-2 simple expansion locomotive (5101) and

(1) Slide valves are still used by some railways for the low pressure cylinders. The French *Nord* Railway follows this practice on its latest superheated compound *Super-Pacific* and *Decapod* locomotives : this Company also retains the slide valves when it superheats the simple expansion suburban engines 3801-3835, 3841-3865.

With regard to the alteration of saturated steam locomotive to superheat, see an article by Mr. Viddecke, published in the 15 February 1927 number of the *Organ für die Fortschritte des Eisenbahnwesens*.

on a 2-10-0 locomotive (No. 5001) also simple expansion.

The principle of this valve is the fol-

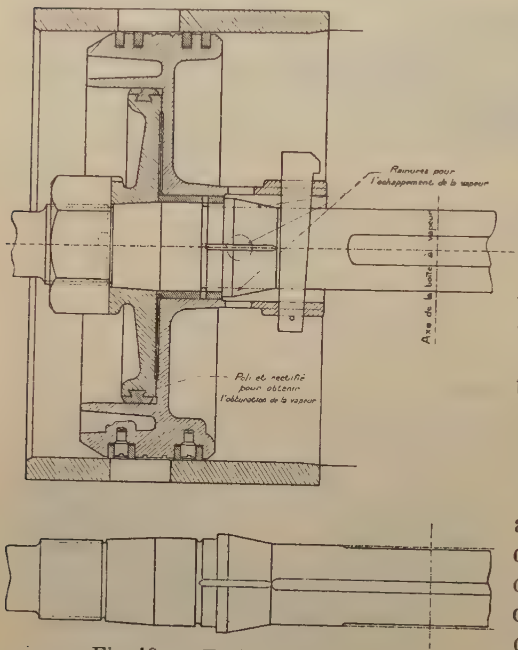

Fig. 18. — Trofinoff piston valve

Explanation of French terms : Axe de la boite à vapeur = Center line of the steam chest. — Poli et rectifié pour obtenir l'obturation de la vapeur = Polished and bedded in order to prevent steam leaking. — Rainures pour l'échappement de la vapeur = Grooves to allow the steam to escape.

lowing : the two piston valve heads can move longitudinally along the spindle between two end plates. When the regulator is open, the pressure of the steam holds the two heads against the corresponding end plates exactly as though they were mechanically secured to the spindle : when the regulator is shut, the pistons remain stationary at the end of their travel on the middle part of the steam chest thereby uncovering the steam ports and putting the two ends of the cylinder into communication with one another.

V. — Valve spindle and piston rod packings.

The railways all use *metallic packings* with the packing rings of *antifriction metal* (Schmidt, King or Sullivan type packings described in the reports to the previous Congresses [1] and in the « Locomotive Cyclopedia of American Practice » [2].

As regards the composition of the antifriction metal, the following are used :

— 80 % lead, 20 % antimony (the *French* Railways; *Madrid, Saragossa & Alicante* Railway; the *Aragon* Railway),

— 76 % lead, 10 % antimony, 14 % tin (*Italian State*),

— 85 % lead, 10 % antimony, 5 % tin (*Andalusian* Railways).

Rings of these alloys unfortunatelly melt as soon as they begin to leak [3]. The frequency with which these packings got out of order whilst formerly allowable, increased in a high proportion when the degree of superheat was raised, and many railways have been led to consider :

— either new alloys as a substitute for those used so far,

— or, new types of packing.

The new alloys under test during the year 1928 were the following :

— 60 % lead, 40 % copper (*Alsace-Lorraine*);

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(1) Report by Mr. Dassesse to the 1910 Congress and of Mr. Lacoin to the 1922 Congress printed in the May 1910 and June 1921 numbers of the *Bulletin of the International Railway Congress Association*.

(2) 1927 edition, page 526 et seq.

(3) In the case of the lead-antimony alloys the composition of the eutechtic is 87 % lead, 13 % antimony and the corresponding melting temperature is 228° C. (442.4° F.).

— B metal formerly known as « Bahnmetal » of 97 % of lead with additions of alcaline-earth metals (*Paris, Lyons & Mediterranean* Railway);

— 99 % lead, 1 % sodium (*Paris, Lyons & Mediterranean*).

The new types of packings are cast iron or *semi-metallic* packings.

a) *Cast iron packing.*

The *Garex* packing is formed of a series, varying in number according to the pressure concerned, of pressure-reducing elements, and steam tight elements, each placed in a casing (fig. 19).

The pressure-reducing elements are formed of castellated rings made of bronze; each ring is made in two pieces.

The steam tight elements are formed of double segments made of soft cast iron; each segment is in three parts.

The stuffing boxes are divided into two pieces.

The castellated rings and the segments are held against the rod by garter springs the tension of the springs being weaker in the case of the castellated rings than with the segments.

The Garex packing has been successfully used on the *Paris, Lyons & Mediterranean* Railway on the H. P. piston and extended piston rods of the 4-8-2 engines, on the other hand, the *Paris-Orleans* Railway has had to give up using them owing to leakage which could not be overcome (after 15 000 km. [9 320 miles]).

The *Hauber* packing is formed of a set, varying in number, of elements each placed in a cast iron cup and formed of doubled segments also of cast iron (fig. 20).

The segments are in three parts, each part being attached to a corresponding adjacent part of the segment by means of a small pin forming a hinge.

The double segments are pressed against the rod by two holding rings in cast iron, the joints of which are placed 180° apart.

The *Paris-Orleans* after having made tests on two locomotives of each of the 4500 S, 5000 S and 6000 S classes compound and superheated locomotives with success, decided to fit the Hauber packing to all the engines of these classes.

This railway considers that these packings remain perfectly steam tight, and that they cost practically nothing for repairs. It considers that the steam tight segments which are the only ones which can wear, should run 150 000 km. (93 200 miles) and that on the classes of engine mentioned, the segments need only be replaced at every second shopping.

The *Alsace-Lorraine* and the *Paris, Lyons & Mediterranean* are also carrying out tests with this packing.

With both the Garex and Hauber packings, the existing stuffing boxes can be used without much alteration. They have the drawback, though it is not very serious, that floating glands have to be used with them.

The advantages and drawbacks both disappear if the stuffing glands are cast with the boxes, as is done with the Est and Huhn labyrinth pattern of cast iron packing.

The Est pattern labyrinth packing with three part segments held to the rod by a garter type spring (fig. 21) has been adopted by the *Est* Railway.

It has given entire satisfaction on this company (no repairs required between two periodic repairs, after running 60 000 km. [37 280 miles]).

The *Huhn* packing shown in figure 22 is being tested on the *Alsace-Lorraine* Railways.

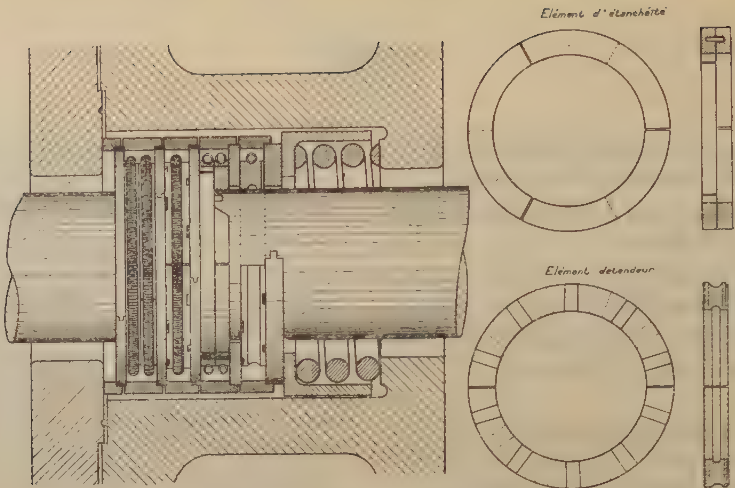


Fig. 19. — *Garex* packing.

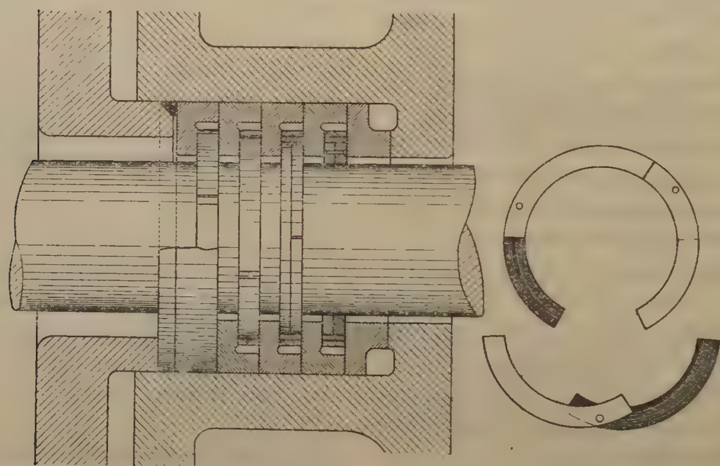


Fig. 20. — *Hauber* packing.

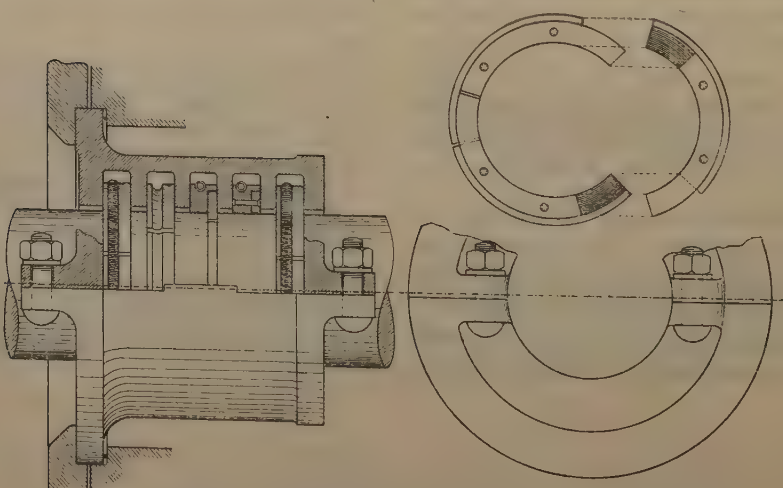


Fig. 21. — *French Est labyrinth* type packing.

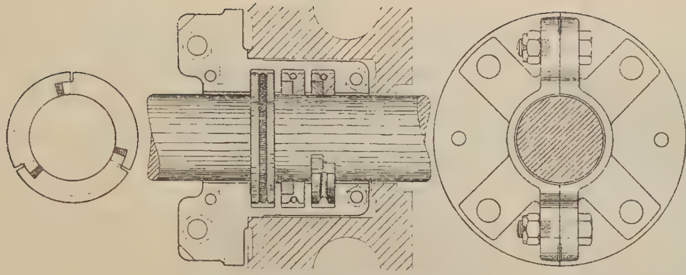


Fig. 22. — *Huhn* packing.

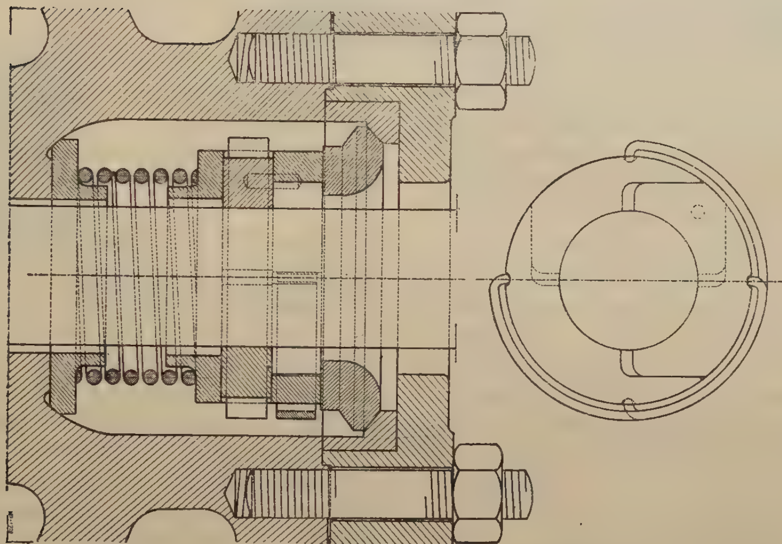


Fig. 23. — *London & North Eastern* packing.

This *Huhn* packing has been tested by the *Reichsbahn* along with other types of cast iron packing (1).

The cast iron packings *of the L.N.E.R. type* used on the *London & North Eastern Railway* should also be noted (fig. 23).

The *Paris, Lyons & Mediterranean* Railway which has tried them, found after a short period of service, a marked wear of the segment with grooving of the piston rods although it was not possible to determine definitely the cause of the lack of success : quality of the cast iron, method of lubrication, quality of the metal of the piston rod, finish of the piston rod...

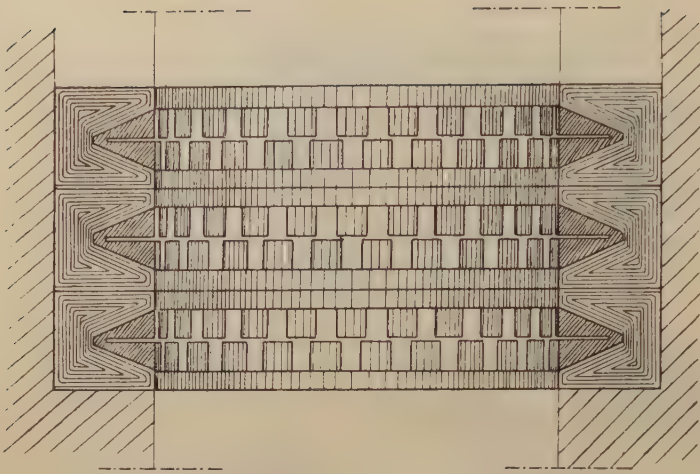
b) *Semi-metallic packings.*

These packings consist of asbestos woven into rope enclosing a ring of antifriction metal.

A trial of the *Amiral-vapeur* packing (fig. 24) is being carried out on the French *Midi Railway.*

The *Paris, Lyons & Mediterranean* Railway has also tested similar types of pack-

(1) Cf. *Organ für die Fortschritte des Eisenbahnwesens* of the 30 June 1927. « Cast iron packings », by Mr. DANNECKER.



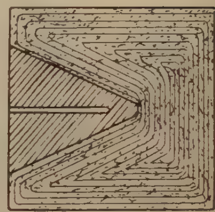


Fig. 24. — *Amiral-Vapeur* packing.

ing, the *Pilot type* (Beldam-Laty) but the alloy would not stand the high superheat temperatures reached.

VI. — Cylinder release valves. Air admission valves. By-pass valves.

No really new designs have been reported in use.

a) *Cylinder release valves.*

The French *Nord* Railway has arranged to increase the number, to have them very accurately adjusted, to follow them up in service, and to calibrate them at frequent intervals.

b) *By-pass valves* (1).

The Companies using *by pass valves* are not in agreement as to the method of con-

(1) See an article in the *Zeitschrift des Vereines deutscher Ingenieure* of the 25 August 1923. « By-pass valves for steam locomotives », by Mr. O. GUNTHER.

The *Andalusian* Railways have a number of automatic by-pass valves with a single valve per cylinder in service, similar to the valves described in the article referred to above.

trolling them. Should they be automatic, hand operated, or servo-motor operated? Although opinions are divided, the tendency appears to be towards hand operated valves as being more certain as well as simpler.

c) *Air admission valves.*

A certain number of the locomotives of the *Madrid to Saragossa and Alicante* and of the *North of Spain* Railways have air admission valves on the saturated side of the superheater headers. This arrangement was adopted to prevent the sudden entry of cold air into the highly heated cylinders : it has also the good feature as mentioned already, of assisting to cool the superheater elements.

Following the same line of thought, the *Belgian State* Railways have tested an anti-vacuum valve *blower* attached to the saturated steam side of the header and controlled by compressed air (the same valve supplies compressed air to the *blower* and to the servo-motor of the by-pass at the same time); a separately controlled steam jet (1) has also been provided in addition, in order to improve the circulation of atmospheric air through the superheater and to assists in keeping the oil in the cylinders in good order.

d) *By-pass and air admittance valves.*

The question as to whether by-pass valves alone, air admittance valves alone, or both by-pass and air admittance valves together should be fitted, has not yet been settled.

The *Aragon* Railways like the *Paris, Lyons & Mediterranean* use the by-pass valves alone, whereas the French *Est* and the French *Nord* favour air admittance valves. Other Companies such as the *Madrid to Saragossa and Alicante*, the *North of Spain* and the *Italian State* Railways consider that both by-pass and air admittance valves should be used together.

The *Paris-Orleans* Railway, which has not taken up any definite position reports : « the use of both by-pass and air valves appears to be an unnecessary complication, as the by-pass is all that is needed when it is of suitable size. In addition, the experiments recently carried out to increase the superheat temperature of the locomotive seem to show that with a superheat exceeding 350° C. (662° F.) the air introduced through the air valve can cause the oil to carbonise after each closing of the regulator, when the walls of the steam chest are still at a very high temperature ».

The *Paris-Orleans* is at the present time developing a by-pass valve which will be free from the drawbacks of the arrangement it has used so far (leakage through the valve the maintenance of which is often costly).

e) *Multiple valves.*

The *del Papa valves* described in the *Rivista Tecnica delle Ferrovie Italiane* of July 1918 are used by the *Italian State* Railways.

They were tried, but subsequently removed, on the *Paris, Lyons & Mediterranean* and the *Paris-Orleans* Railways; the latter Company's chief objection was their too high first cost.

C. — CONCLUSIONS.

a) Temperatures of the order of 400° C. (752° F.) for compound locomotives and

(1) Cf. *Bulletin of the International Railway Congress Association*, August 1926. *Op. cit.*

350° (662° F.) for simple expansion locomotives ought to be used generally;

b) In order to arrive at the correct proportion of the parts of superheaters, the various factors given below must be taken into account :

— ratio of the area of the steam passages through the superheating elements to the grate area;

— ratio of the superheating surface to the heating surface;

— ratio of the resistance opposed to the passage of the combustion gases through the nest of flue tubes to that through the boiler tubes, or possibly, as the calculation of the resistance is frequently very difficult, the ratio of the section of passage of the gases through the nest of flue tubes to that through the nest of boiler tubes;

c) The layout adopted for the superheaters and for the parts connected with the application of superheating tend as a general rule to become uniform (the almost exclusive use of superheaters with large flue tubes and of piston valves);

d) The displacement and mechanical lubricators ensure that the lubrication is ample and regular, provided they are fitted with suitable non return valves;

e) When the superheat is high, cast iron piston rod and valve spindle rod packings should be used;

f) The question as to whether by-pass valves alone, air admittance valves, alone, or by-pass valves with air admittance valves are to be used awaits answer.

CHAPTER III.

Feed water heating.

The feed water heaters are at the present time still in process of development. The manufacturers are applying to their equipment as occasion offers, the alterations in detail, and even in principle, suggested by practical experience : so much so, that any maker who has previously delivered heaters not quite perfected, can now offer designs which will give satisfaction. Consequently, it is not surprising to find the railway companies hold different opinions, from the technical point of view alone, on the one hand upon the products of a particular firm, and on the other, on the order of merit of the designs of the different firms : this is due to tests having been made with heaters which were not identical.

An endeavour will be made in the following notes, so far as the information received allows, to bring out the special features of the heaters dealt with, in the most definite way possible.

A. — Feed water heating by exhaust steam.

I. — General characteristics of the heaters.

The tables A, B, C, D give the general characteristics of the various type of heaters using exhaust steam :

— table A, injectors,
— table B, open type heaters [1],
— table C, closed type heaters [1],
— table D, multi stage heaters.

---

[1] Surface mixing feed water heaters are classified into the « *open* » and « *closed* » types, as the condenser is, or is not under pressure.

The notes on tables B and C show to which type, open or closed, the various feed water heaters mentioned belong.

No other information on the heaters other than the very brief notes on the tables A to D will be given. Complete descriptions of the various types of heaters have appeared in different technical journals (1).

(1) — Cf. *Société d'Encouragement pour l'Industrie Nationale.* Bulletin of February 1925 — For the ACFI Type RM, feed water heaters. Bulletin of November 1928 — For the Dabeg heaters.

Rivista Tecnica delle Ferrovie Italiane. — April 1926 number — for the Knorr feed water heaters and for the Friedmann type LF injectors.

The Engineer — 17 August 1928 number — for the type H Metcalfe injector.

Locomotive Cyclopedia of American Practice — 1927 edition, page 325 et seq. — for the Elesco, Coffin, Worthington type BZ and the Elesco and Sellers injectors.

TABLE A. — **Exhaust steam injectors.**

Type.	*Characteristics.*		
METCALFE types D.	...	The manufacture of the type appears to have been given up.	
METCALFE types F.	The type F is an improvement on type D.	...	
METCALFE types G.	Type G only differs from type F in the location of certain control fittings.	...	The injector has *1 single se* cones. 1 *supplementary life ste* cone. 1 *exhaust steam* cone. 2 suction tubes. 1 mixing cone. 1 feed cone.
METCALFE types H.	This type is *automatically controlled*, i. e. live steam is automatically substituded for exhaust steam when the regulator is closed.	Identical fittings with the exception of minor details (the position of the automatic valve is not the same).	
FRIEDMANN type LF.	Do.		
ELESCO type SF.	Do.	Very similar [1] to the type H. Metcalfe injector.	
SELLERS.	Do.	...	The injector has 2 *sets of cor* the first set (exhaust stea and feeding under pressu the second set (live ste tubes) working with *live ste from the boiler*.
CAPROTTI.	...	...	The fitting is composed of : an exhaust steam injector, two reservoirs placed on barrel of the boiler, one which is open to the atr sphere when the other in communication with boiler. The injector forces the f water which is heated mixing with the exhaust ste into the reservoir open to atmosphere whilst the hea water in the other reserv falls by gravity into the boil When the respective ope tions of filling up and empty are completed, the functi of the reservoirs are rever by means of suitable valv when a new cycle of operat again starts.

(1) We have little information concerning the Elesco injector.

Feed water heaters with exhaust steam condensers.

Feed pumps. Kind and number.	Feed pumps. Type.		Feed pumps. Drive.		Name of fitting.	Remarks.
1 *cold* water pump	Centrifugal pump.		Steam turbine.	Single stage.	COFFIN.	Condensed water returned to tender.
	Double acting reciprocating pump.	1 cylinder.	Donkey pump.	Single cylinder simple expansion.	WEIR.	
					ELESCO with W-6 1/2 pump.	Condensed water returned to tender.
					KNORR.	
				2 cylinders compound.	NIELEBOCK-KNORR.	Condensed water returned to tender.
		2 cylinders.	Donkey pump per water cylinder.	2 cylinders simple expansion.	ELESCO with CF pump.	do.
1 *hot* water pump	Double acting reciprocating pump.	1 cylinder.	Donkey pump.	Single cylinder simple expansion.	CCP improved ACFI.	The manufacture of this pattern appears to have been discontinued.
1 *cold* water pump and 1 *hot* water pump.	Double acting reciprocating pump.	1-cylinder pump	Donkey pump.	Single cylinder simple expansion.	ACFI type RS.	The manufacture of this pattern appears to have been discontinued.

Nota. — In equipments with only a cold water pump and belonging to the « *closed type* », the feed water is forced through the nest of tubes of the condenser, and the nest is consequently subjected to *high* pressure (slightly higher than that of the boiler).

In equipments having a hot water pump (with or without a cold water pump) and which belong to the « open » type, the feed water circulates on the outside of the nest of tubes of the condensers. Exhaust steam circulates through the inside of the tubes which are consequently subjected to a *very low* pressure.

TABLE C. — **Exhaust**

Feed pumps.				
Kind and number.	Type.		Drive.	
1 *cold* water pump and 1 *hot* water pump.	The two pumps are double-acting reciprocating pumps.	1-cylinder pump.	Donkey pump.	1 simple exp cylinder
			Locomotive driving gear.	
	The two pumps are single stroke reciprocating pumps.	1 cylinder pump.	Locomotive driving gear.	
	The cold water pump is a centrifugal pump.		Single stage turbine pump.	
	The hot water pump is a double acting reciprocating pump.	1 cylinder.	Donkey pump.	1 simple ex cylinde

Nota. — The various heaters belong to the "open type" except in the

vater heaters.

Name of fitting.		Remarks.		
ACFI types	RM.	The equipment includes a "temperature control" which is intended to limit the pressure in the condensers to a *rather low figure* which is however sufficient to raise the feed water temperature to about 95° C. (203° F.)		
	RM Integral.	The equipment which no longer includes the " temperature control " has been designed to use, in the condenser, steam *at any pressure*.		
THINGTON types	A.	Self contained heater with vertical pump.	Return of excess water controlled by floatvalve.	The manufacture of these types of heater has apparently been given up.
	B.	do.	do.	
	BZ.	do	do.	
	AY.	do.	Return of excess water controlled by ejector.	
	AX.	Heater with separate pump and condenser (horizontal pump).	do.	
DABEG type DOF.		...		
EG types	A 120 VR 1 and A 120 HR 1 or S 120.	Only differ by detail improvements introduced in the heaters (the list of types is given in the order in which they were introduced by the Dabeg Company.)		The manufacture of these types of heater has apparently been given up.
	A 120 HR 2 and A 140 HR 2 ...			
	120 A and 100 A ...			
WORTHINGTON type S.		...		

FI type RM Integral which is of the " closed type ".

TABLE D.

Multi-stage exhaust steam feed water heaters.

Type of equipment.	*Characteristics.*
WESTINGHOUSE-DELAS.	The equipment consists of, in series : — an *exhaust steam injector* — a *mixing heater.* The injector forces the feed water after being preliminarily heated into the condenser of the heater. A hot water pump driven by a donkey engine draws the water from the condenser and pumps it into the boiler, the water having been given its second stage of heating.

II. — Statistics of the numbers of feed water heaters in use.

Table E gives the position, in 1928, as regards feed water heating on the Railway Companies enumerated in appendix II.

This table shows that the fitting of feed water heaters has already become very extensive on certain railways (*North of Spain, Alsace-Lorraine, Paris, Lyons & Mediterranean*).

III. — Comparative tests of different types of heaters. Results obtained.

Madrid to Saragossa and Alicante Railway.

The surface or « open » heaters, CCP and KNORR have had to be removed owing to considerable scaling up which reduced their efficiency.

The WORTHINGTON type BZ, the DABEG S-120 and 120-A and the METCALFE types F and H injectors working on the closed system, are still undergoing test : the Company states that the results given by the DABEG heater, so far, are better than those obtained from the other makers.

North of Spain Railway.

The KNORR open heaters have been given up.

The METCALFE injectors, the closed heaters of the DABEG, WORTHINGTON and the ACFI type RM patterns, the latter of recent introduction, have given satisfactory results.

Alsace-Lorraine Railways.

This railway has made tests with the open type KNORR heaters, the closed type ACFI, type RM and the METCALFE injectors.

It has obtained the best results with the ACFI, type RM heaters.

Taken on the total coal used, this latter type has shown a fuel economy of 9 to 12 %, as compared with the 8 to 10 % with the KNORR heaters and 5 to 6 % with the METCALFE injectors.

The *Alsace-Lorraine* states that taking into account the cost price, the cost of fitting, and the repairs, the time to pay off the ACFI, type RM heater, is about three years.

French State Railways.

This railway has tested open heaters of the CCP type, improved ACFI, and subsequently the closed type RM ACFI heaters. These last which work satisfactorily give better results than the others, and show a saving of 7 to 9 % on the total fuel used.

This railway is carrying out tests with METCALFE injectors and WORTHINGTON closed type heaters, and is about to try the closed type DABEG 120-A pattern heater.

The ACFI, type RM heater will pay for itself in 3 1/2 years.

French Nord Railway.

The type RM ACFI heaters give satisfaction.

The Company is considering the question of carrying out comparative tests with those of other makes.

Paris, Lyons & Mediterranean Railway.

The conclusions from the tests carried out are the following :

1. *Exhaust steam injectors.*

The METCALFE type F injectors although very simple in maintenance, have not given the results expected.

They have shown only a slight economy of fuel : this result appears to be due especially, to the difficulty of ensuring that the enginemen properly regulate the supplementary supply of live steam from the boiler.

2. *Feed water heaters properly so called.*

a) Whatever type of heater be used the costs of the fitting the engine can be paid off quickly.

The heaters tested have resulted in :

— a saving of about 8 % less fuel at equal power of the locomotive,

— an increase of 10 % in the load hauled by the locomotive for equal fuel consumption.

b) The *closed* type heaters give better results than the *open type*.

They are simpler and require much less maintenance.

c) Of the closed types heaters tested (WORTHINGTON type BZ, ACFI type RM, DABEG type HR-2), the ACFI type RM and the DABEG type HR-2 can be considered as equal, the WORTHINGTON type BZ being slightly inferior (it has certain drawbacks particularly in connection with the float).

The *Paris, Lyons & Mediterranean* Railway is now (1929) making tests with two new designs, the ACFI type RM Integral, and the WORTHINGTON type AX.

Paris-Orleans Railway.

The results obtained in service with the METCALFE injector have varied considerably for the same reason as that mentioned by the *Paris, Lyons & Mediterranean Railway*, namely the difficulty of working them efficiently.

The *Paris-Orleans* considers the ACFI type RM heater as being well thought out: it is also carrying out experiments with other types of heater.

Est and *Midi Railways.*

These two companies have not yet completed their trials.

Italian State Railways.

The *Rivista Tecnica delle Ferrovie Italiane* published in the April and May 1926

TABLE E. — **Position during 1928 on the various Rai**

—			SPAIN. Madrid to Saragossa and Alicante.	SPAIN. North of Spain.	Alsace-Lorraine.	Es
Exhaust steam injectors.	METCALFE.	D	?	...	...	...
		F and G	...	?	3	109
		H	?	...	...	1
	FRIEDMANN LF.		...	...	...	...
		Total	?	?	3	110
Feed water heaters. surface or open type.	CCP improved	. ACFI.	?	...	...	...
	ACFI.	. RS	...	. .	...	...
	KNORR		?	?	589(2)	...
		Total	?	?	589	...
Feed water heaters. closed type.	WORTHINGTON.	A	...	...	. .	...
		B	...		...	2
		BZ	?	336	...	...
		AX.	...		...	...
	ACFI.	RM.	...	?	370	2
		RM Integral.	...	...	...	...
	DABEG.	A 120 VR$_1$ and A 120 HR$_1$ or S-120	2	1	...	...
		A 120 and 140 HR$_2$.	2	...	...	2
		120 and 100 A.	90	20	. .	2
	WESTINGHOUSE-DELAS		...	..	...	1
		Total	?	357	370	9
		Grand total applied. (T)	?	357	962	119
Number of steam locomotives belonging to the Railways at the 1-1-1928 (shunting engines not included.) (N)			1080	1130	1483	227
Percentage of locomotives fitted		$\left(100\frac{T}{N}\right.$	?	32 %	65 %	5 %

(1) The table also includes equipments on order, or ordered, for 1928.
(2) Feed water heaters fitted to locomotives of German origin.

merated in Appendix II of feed water heating by exhaust steam.

	FRANCE, COLONIES AND PROTECTORATES.									ITALY.
tate.	Midi.	Nord.	Paris, Lyons & Mediterranean.	Paris-Orleans.	State Rys. (Algerian system).	Paris, Lyons & Mediterranean (Algerian system).	Tunisian Rys.	Damas-Hamah.	Smyrna-Cassaba.	State.
...	...	...	...	3	...	...	...	...	...	...
2	42	...	6	205	...	..	5	...	...	...
...	...	...	...	1	...	...	...	...	...	...
...	...	...	...	...	...	...	...	..	...	120
2	42	...	6	209	...	...	5	...	...	120
20	...	60	99	...	10	...	...	...	..	...
...	...	...	1	...	...	...	...	...	...	...
...	...	...	126(2)	24(2)	...	...	...	...	...	..
20	...	60	226	24	10	...	...	...	...	...
...	...	...	3	5	...	...	...	...	...	...
...	...	...	5	...	...	1	...	...	...	...
10	...	...	19	...	...	...	...	...	...	...
2	...	...	10	5	...	4	...	...	...	...
140	11	143	530	10	15	20	3	40	29	...
...	...	...	1	...	...	...	...	...	...	...
...	...	...	10	...	...	...	...	...	...	...
...	...	...	130	...	...	...	...	..	..	...
50	...	2	66	...	...	...	...	...	...	...
...	...	..	..	...	...	..	..	...	...	...
202	11	145	774	20	15	25	3	40	29	...
224	53	205	1006	253	25	25	8	40	29	120
3676	1150	2425	5032	2213	420	224	215	46	35	5727
6 %	5 %	8 %	20 %	11 %	6 %	11 %	4 %	87 %	83 %	2 %

numbers, a report by the Engineer G. Corbellini, on the tests carried out on the *Italian State* Railways with locomotive feed water heaters.

This report should be consulted for details of the trials, only the conclusions formulated being reproduced below.

1. *All types of feed water heaters with pumps give practically equal results.*

2. From the overall technical balance sheet, it appears that the value to be obtained by the use of feed water heaters *is always small* in Italy as with the present price of the equipment the final saving is only about 2.5 % of the cost of the fuel used by a medium power locomotive used under average conditions : in all events the use of feed water heaters is limited to the locomotives working express trains and those in mountain country, that is to say, to those with which the boiler has to be fed constantly, or almost so, whilst running with the regulator open.

In the case of locomotives working stopping trains, the overall balance sheet of the economy obtained shows a nil result, or even a loss.

3. From the point of view of the practicability of equiping Italian locomotives with heaters, the weight is such an obstacle, that in many cases the pump driven heater can not be fitted : as a result, the field of application is restricted to apparatus of light weight.

4. In particular :

a) The ACFI type RM heater has introduced the complication of fitting a hot water pump, solely to satisfactorily purify the water, the practical value of which has not been proved.

b) The KNORR heater is simpler than the ACFI : it does not purify the water at all and its cost is greater

c) *The Friedmann injector, although it gives a lower thermal efficiency* [1] *is to be preferred to the two designs with pumps,* both because of its low price and because it is cheaper to maintain : finally, the increase in the weight of the locomotive due to it is negligible.

The conclusions under *a*), *b*) and *c*) of course only relate to the types of heaters tested.

The *Italian State Railways* have also experienced with the WORTHINGTON type B (or BZ) heaters the same drawbacks as that noted by the *Paris, Lyons & Mediterranean* Railway, namely irregular working of the float due as a result of scale.

From the above summary, a definite idea at once emerges, that the surface heaters are no longer liked and tend to disappear (because they are less simple and have a lower efficiency than the closed heaters). We can then note that certain closed type heaters are satisfactory without however being able to bring out the marked superiority of any particular type of heater.

IV. — Various data on the feed water heaters.

a) *Increase in weight.*

According to the *Paris, Lyons & Mediterranean Railway*, the increase in the

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[1] The *Italian State Railways* have found a saving of fuel of 6 % with the Friedmann injectors and 7 % with the KNORR and ACFI type RM heaters.

weight of the locomotive due to fitting it with a feed water heater (as compared with the weight when fitted with the ordinary injector) is as follows :

Type of heaters.	Pattern.	Increase in weight.
Open type heaters.	CCP improved, ACFI with 210 pump. [*Hourly rate 12* ^{m3} (*44 cubic feet.*)]	1 500 to 2 000 kgr. (3 300 to 4 400 lb.)
		1 400 kgr. (3 090 lb.)
	ACFI type RM with 254 pump. *Hourly rate 17*^{m3} (*600 cubic feet.*]	1 800 kgr. (3 970 lb.)
Closed type heaters.	DABEG types 120 A et 140 A.	1 000 to 1 100 kgr. (2 200 to 2 420 lb.)
	WORTHINGTON type 2 BZ.	1 400 kgr. (3 090 lb.)
Injectors.	METCALFE.	200 kgr. (440 lb.)

The above figures vary up and down from one railway to another.

In any event, fitting a locomotive with a feed water heater increases the weight by 1 to 2 tons (according to the type fitted) whereas the exhaust steam injector only involves an insignificant increase.

b) *Handling the heaters in service.*

The heaters are simple to operate.

The working of the pump can be followed either by a beat indicator or by the strokes of a mechanical lubricator. An injector is known to be working by sight and sound.

Pyrometers or thermo couples indicate if the water is properly heated. These latter instruments are not altogether satisfactory.

c) *Temperature obtained.*

The average temperature of the feed water on leaving the feed water heaters is about 95° C. (203° F.) (1) when running with the regulator open. The temperature of the feed water does not vary by more than 6 to 7° C. (11 to 13° F.) from the average temperature.

d) *Tests made as to capacity and the power absorbed.*

The results of tests made on the *Paris, Lyons & Mediterranean* Railway with the

(1) With the ACFI type RM Integral, the *Alsace-Lorraine* Railways have obtained temperatures exceeding 100° C. (212° F.) on a simple expansion locomotive of the G 14 class (back pressure at the exhaust rather high : 0.3 to 0.4 kgr. [4.27 to 5.69 lb.]).

different types of feed water heaters in service on its locomotives are summarized in the following table :

—	Feed water heaters.			
	A. C. F. I.	Worthington.	Dabeg.	
Pattern	RM with 254 × 203 × 203 pump	2 BZ	A. 120	A. 140
Maximum capacity . . .	17 m³ (600 cubic feet).	15 m³ (530 cubic feet).	24 m³ (848 cubic feet).	26 m³ (918 cubic feet).
Corresponding speed strokes per minute.	25	65	300	300
Steam consumed, or power absorbed by the pump when working (1) . . .	3 % approximately of the volume of water pumped in to the boiler.	3 % approximately of the volume of water pumped in to the boiler.	22 H. P. at full capacity.	30 H. P. at full capacity.

e) *Effect on the superheat temperature.*

Records taken on the *Paris, Lyons & Mediterranean Railway* on two locomotives before and after equipping them with the ACFI type RM heater showed that there was a loss of 5 to 10° C. (9 to 18° F.) in the superheat temperature.

In America, a variation of 15° C. (27° F.) has been found (2).

(1) Cf. *Organ für die Fortschritte des Eisenbahnwesens*, 1 August 1928, page 293. « Tests with locomotive feed pumps », by Mr. L. Schneider.

The Author compares the Knorr compound and simple expansion pumps : he shows that on the one hand, the steam consumption of the former is definitely lower than that of the latter, and on the other that with the two types of pump the consumption (per indicated H. P.) falls as the number of strokes increases.

See also the same Paper for the 15 February 1929, page 65.

(2) Cf. *Railway Mechanical Engineer*, July 1923, page 511. « Proceedings of Division V, Mechanical- American Railway Association », Chicago, 20-22 June 1923.

f) *Effect on the draft.*

No report has been received to the effect that taking exhaust steam for feed water heating has even a slight unfavourable action on the draft.

There is certainly a reduction in the strength of the draft but this reduction is corelated to that of the activity of combustion on the grate.

g) *Reduction in cylinder back pressure.*

The *Paris-Orleans* has found a reduction of about 20 % with equal blast pipe openings.

h) *Effect upon the cost of boiler maintenance.*

So far as we are aware, the influence of feed water heaters upon the cost of boiler repairs has only been gone into systematically on the *Chicago Milwaukee, St. Paul & Pacific Railroad* (1).

(1) Cf. *Railway Age*, 17 March 1928. The reduction of boiler corrosion when feed water heaters are fitted, by C. H. Koyl.

The comparative trials carried out on this railway with two identical locomotives with new tubes, one fitted with a surface type heater (that is to say with the condenser in communication with the atmosphere) have shown that the tubes of the locomotive with the feed water heater corroded very slightly, whereas on the others the corrosian was so serious that a certain number of tubes had to be replaced.

The results obtained are due to the gases in the water being removed before the water gets into the boiler : the elimination of oxygen would in fact as a consequence limit, and even suppress the phenomena of electrolysis which occur inside the boiler in an alkaline solution.

i) *Oil separators.*

The Companies using closed type heaters have not found any ill effects due to the presence of traces of oil [1] in the feed water.

j) *Equipment for preventing cold water from being fed to the boiler when the regulator is shut.*

Some railways consider it advisable to fit additional equipment *automatic in action* in order to prevent cold water being pumped into the boiler when the regulator is shut.

The equipment, which is very simple, is intended, on the regulator being shut, to :

— stop the pump,

— substitute live steam for the exhaust steam.

These devices consists principally of differential valves, one side of which is subjected to the pressure of the boiler, and the other to that of the steam chest.

k) *Maintenance of the equipment.*

The ordinary running maintenance of the heaters includes the removal of scale, the frequency of which depends upon the hardness of the water used.

As a rule, scale is removed by using a solution of hydrochloric acid (of 15 to 20 %).

As regards the actual costs of maintenance, the *Alsace-Lorraine* Railway has supplied the following figures :

KNORR open type :

778 fr. per equipment per annum;

29.15 fr. per 1 000 train-km. (46.91 fr. per 1 000 train-miles).

ACFI type RM closed type :

573 fr. per equipment per annum;

21.60 fr. per 1 000 train-km. (34.76 fr. per 1 000 train-miles).

l) *Defects.*

The Companies have not reported anything in particular as to the way the various details of the heaters have stood up in service.

The *French Nord* and the *Paris, Lyons & Mediterranean* Railways report that cases have occurred in which water has been carried over into the cylinders : this defect has disappeared since scale has been removed more frequently, and a special device (vacuum breaker) has been fitted between the two reservoirs. There should be no danger of the heaters freezing up if the enginemen carefully carry out the makers' instructions.

(1) In the case of the ACFI type RM heaters, on the *Alsace-Lorraine* Railways the proportion of such oil does not exceed a few milligrammes per litre of water.

m) *Saving of fuel and water.*

The *fuel saving* was given above when dealing with the trial carried out by the different railways. It varies very considerably, according to the type of equipment and the using Company, that is to say, according to the conditions under which it is used : it appears to vary for feed water heaters properly speaking, between 8 and 9 % if calculated on the coal used as a whole and round 15 % if calculated on the coal used during the time the pump is working (that is when the regulator is open).

The saving of water is not appreciable except with the closed type heater [1]. It is about 15 % with the ACFI type RM heaters (*Alsace-Lorraine* and *French State Railways*).

V. — Reserve supply of hot water.

When driving an engine fitted with injectors alone, the driver takes advantage of every period when the regulator is closed to feed the boiler. It is therefore natural that through habit, and in spite of any instructions issued, he should do the same in the case of an engine fitted with a feed water heater. This leads him to use the injector each time the regulator is closed, at least until he has become convinced that he can get more economical results by a different method of working.

This is the reason why feed water heaters fitted on locomotives running over lines with many changes of gradient, or when working trains stopping frequently, have often shown no appreciable saving of fuel.

(1) In the case of the open type heaters any saving of water, other things being alike, can only be due to reduced back pressure.

In order to overcome this drawback, undoubtedly a serious one during the whole of the early period of fitting, the *Auxiliaire des Chemins de fer Company* (ACFI) has provided a *reservoir containing hot water* which can be drawn on when the regulator is closed.

The layout [1] makes it possible by simply working a valve placed in the engine cab :

— either to build up a reserve supply of hot water whilst feeding the boiler when the regulator is open,

— or, without feeding the boiler, to form a reserve storage of hot water during the same periods,

— and in any event, to feed the boiler whether during the time the regulator is shut, or when the engine is stopped with water from the reserve supply already made.

It consists of :

— a reserve of 500 to 1 000 litres (110 to 220 British gallons),

— 2 by-pass valves,

— a three way cook placed in the cab.

The increase in weight due to fitting this additional equipment, is not much more than that of the water in the reservoir: it is therefore about 500 to 1 000 kgr. (1 100 to 2 200 lb.) according to circumstances. This increase is however practically negligible on tank engines if care is taken to form the reservoir by dividing off one of the water tanks.

The *Alsace-Lorraine* has applied for trial purposes, the *hot water reservoir* on 11 locomotives fitted with ACFI heaters.

(1) Cf. *Revue Générale des chemins de fer*, June 1925 : « Le réchauffage de l'eau d'alimentation des chaudières de locomotives sur le réseau d'Alsace-Lorraine. » (The preheating of locomotive boiler feed water on the *Alsace-Lorraine* Railway), by Mr. Boulière.

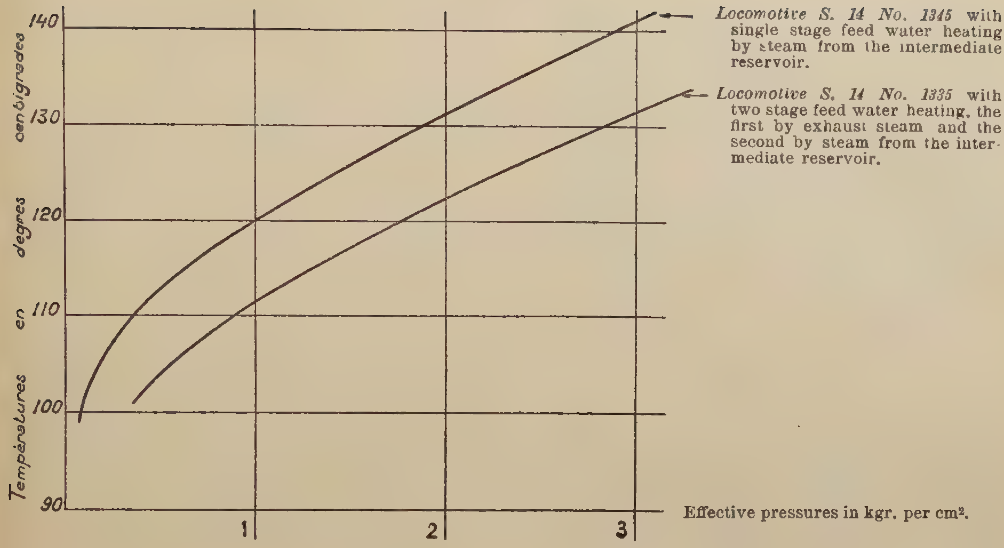


Fig. 25.

The results obtained having been very satisfactory, this Company is fitting up 70 further locomotives in the same way.

The CAPROTTI feed water heater (see table A above) is moreover a design in which each of the two reservoirs forms in turn a reserve supply of hot water.

VI. — Steam from the intermediate reservoir.

Several railways have tried, or are in course of so doing, on compound locomotives to heat the feed water by means of steam taken from the intermediate reservoir.

The *Alsace-Lorraine* Railways have made the two following trials :

1. Heating the water (with an ACFI type RM Integral heater) with steam from the intermediate reservoir;

2. Heating the water in two stages with exhaust steam (in an ACFI type RM heater) followed by heating with steam from the intermediate reservoir (in a KNORR heater placed in series with and after the ACFI heater).

The tests have been made in each case, on a single locomotive (type S-14) and showed, in comparison with the ordinary locomotive, a saving of 17.6 % per 100 tonne-kilometres with the first arrangement, and 16.4 % per 100 tonne-kilometres with the second.

Figure 25 gives the temperature attained by the feed water.

The *Alsace-Lorraine* Railways are continuing the tests undertaken, by taking in particular, series of indicator diagrams on the 4 cylinders of the two locomotives under varying running conditions.

The *Paris, Lyons & Mediterranean* Railway is about to test the preheating of the feed water (in a ACFI type RM Integral heater) with steam taken at the same time from the intermediate reservoir and the exhaust.

The *Paris-Orleans* Railway is carrying

out tests with the exhaust steam injector taking steam from the intermediate reservoir. It found a very interesting re sult, that the total indicated horse power of the locomotive was not reduced but that under the condition under which steam was taken from the intermediate reservoir, the ratio between the work done in the HP and LP cylinders changed from 1.5 to 1.8 which in no way matters.

B. — Heating the feed water by the combustion gases.

Some Companies (the *Madrid to Saragossa and Alicante* and the *Paris, Lyons & Mediterranean*) have put in hand trials with the DABEG economisers intended to recover the heat lost in the combustion gases.

The principle on which these economisers work, is as follows : the feed water raised to a temperature approaching 95° C. (203° F.) by passing through an exhaust steam feed water heater is not fed directly to the boiler; before doing so, it is sent through a series of feed water heating tubes similar to superheater elements placed in some of the flue tubes.

There are two patterns of DABEG economisers [1]:

— the pattern with *separate elements* in which the feed water heating element occupies the whole of the superheater flue tube the corresponding superheater element being suppressed,

— the pattern with *mixed elements* in which there is in the same superheater flue tube, a superheater element together with a feed water heater element [2].

(1) Cf. *Chaleur et Industrie*, November 1928, page 528.

(2) See chapter II, A-1-a.

The *Paris, Lyons & Mediterranean* Railway sums up as follows the results obtained with these economisers :

— the temperature of the feed water has been raised to 150° C. (302° F.),

— the temperature of the combustion gases has been lowered by 50° C. (90° F.),

— the temperature of the superheater has been reduced by 15 to 20° C. (27 to 36° F.).

These are valuable results (in spite of the reduction of the superheat temperature). It remains to be seen how the economisers will stand up in service, *and in particular as regards scaling up.*

C. — CONCLUSIONS.

A. — *Feed water heating by exhaust steam.*

a) The heating of feed water by exhaust steam is a *practical* method of appreciably improving the efficiency of locomotives;

b) The closed type heaters tend to be used in place of the open type;

c) Various types of feed water heaters are in existence which are giving satisfaction but there is no particular design clearly superior to the others and which should be adopted generally.

The question of weight may be the determining factor when selecting a design of equipment.

B. — *Feed water heating by the combustion gases.*

Feed water heating by the combustion gases is so far still in the experimental stage.

CHAPTER IV.

Air preheating.

None of the railways given in appendix II has carried out tests on the preheating of the air supplied to the firebox.

This improvement has only been applied so far as we are aware, to locomotives of new types [Ljungström turbine locomotives (1) and the high pressure (850 lb. per square inch) Winterthur locomotive (2)].

As the preheating of the air should increase *to an appreciable degree* the efficiency of locomotives, it is most desirable it should be adapted in a practical form to locomotives of the ordinary type.

CHAPTER V.

Valve motion.

A. — Improvements in the present types of valve motion.

I. — Present type of motion.

The *Walschaerts* motion at the present time is fitted almost exclusively.

II. — Long stroke motion.

The French *Est* Railway has carried out trials with long stroke motions giving a steam lap of 40 to 50 mm. (1 9/16 to 1 11/32 inches) in order to improve the freedom of running of the locomotives at high speeds.

This Company has sent in the following note explaining the reasons for carrying out the test and the results obtained :

If under normal running conditions the cross section through the steam passages in the valves of a single expansion locomotive, and in the low pressure valves of a compound locomotive are compared, it will be found that especially as regards the exhaust, the low pressure ports of the compound engine are as a rule much greater than those of the simple expansion engine although the exhaust steam is substantially under the same condition of pressure and temperature in the two machines. This difference explains the greater freedom of running generally found in the case of compound locomotives.

It was therefore natural to endeavour to make the simple expansion locomotive equally free running at high speeds by increasing the area of the steam passages through the valves.

The so-called long stroke valve gear enables this increase in sectional area to be obtained : this gear is fitted to the 50 tank engines Nos. 32001 to 32050, type 2-6-2, put into service in 1925 by the Company for working passenger trains (Suburban service).

These locomotives have Walschaerts valve gear with piston valves. The maximum stoke of the valves is 273 mm. (10 3/4 inches) whereas on locomotives built previously, it did not exceed 135 mm. (5 5/16 inches) that is barely half. The steam lap has been increased from 27 mm. (1 5/64 inches) to 50 mm. (1 63/64 inches).

The piston valve having a longer stroke has a higher speed and consequently opens the ports more quickly which considerably reduces the losses through wire drawing of the steam. A further cause of reduction of these losses, is that at equal cut off the maximum opening of the valve with a long stroke gear is much greater than that of a valve driven by an ordinary motion.

(1) Cf. *Bulletin of the International Railway Congress Association*, May 1928, page 429.

(2) Cf. *Bulletin of the International Railway Congress Association*, January 1929, page 75.

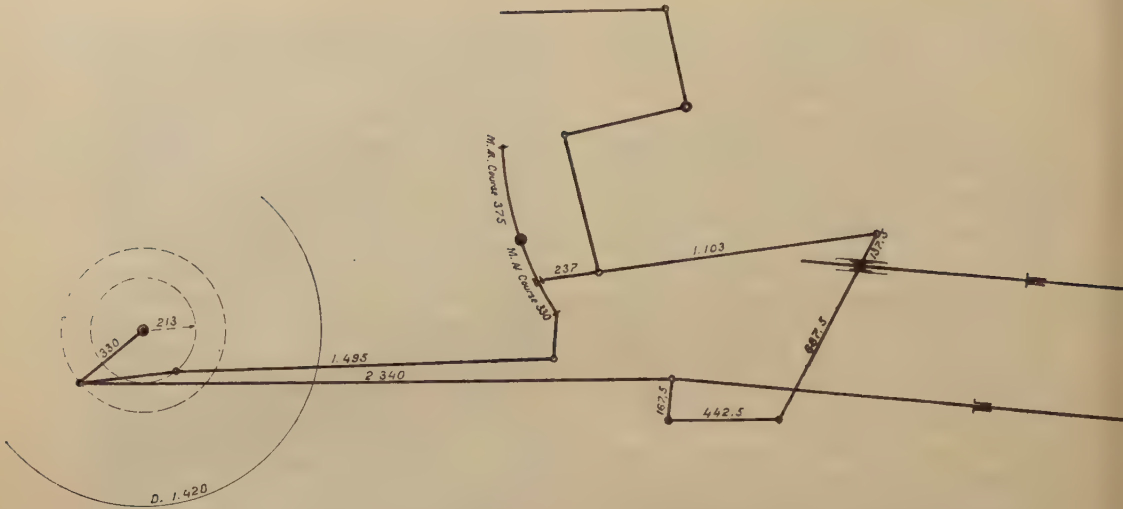


Fig. 26. — Long stroke valve gear on the 32 000 class locomotives of the *French Est Railway.*

This feature makes it possible to run with the long stroke gear at very early cuts off, 30, 20, and even 15 %, without the losses by wiredrawing becoming greater than the savings. These earlier cuts off can moreover show great economies with simple expansion locomotives.

It has been possible to verify in practice the different theoretical improvements given above by comparing the class 32 000 locomotives with the 30 000 type which except in the motion have almost the same characteristics (the 32 000 class locomotives with long stroke valve gear have the drawback from the point of view of cost of having larger cylinders than the 30 000 class with ordinary valve gear).

The comparative trials between these two classes of locomotives were carried out under ordinary working conditions by allocating four locomotives of each class to the some working roster. The tests were continued over a period of eight months, the sets of enginemen being changed over at the end of four months. The saving of fuel was over 4 % in favour of the 32 000 class engines (4.06 % per train-kilometre, and 4.39 % per 100 tonne-kilometres).

. . . .

The long stroke motion has the further advantage of making the 32 000 class engines freer running. With 1.42-m. (4 ft. 7 29/32) in.) diameter coupled wheels these locomotives can attain and even exceed, 100 km. (62 miles) per hour. In ordinary working, the maximum speed is limited to 90 km. (56 miles) an hour.

Figure 26 gives the principal characteristics of the motion of the 32 000 class locomotive. In particular the long stroke of the block in the link (705 mm. = 27 3/4 inches) and the high value (0.20) of the ratio of the two arms of the admission lever will be noted.

III. — Conjugated motions.

As a general rule, each valve is driven by a complete separate valve gear (admission lever, link and eccentric).

None the less, in order to simplify at one

and the same time the inside valve gears, the design of the crank axle and the reversing gear itself (one screw in place of two), designs have been introduced by means of which the outside valve gears drive the inside valves so that the valve motions have been *conjugated* (1).

1. — Simple expansion locomotives.

a) *4-cylinder locomotives.*

The problem in this case is very easy to solve owing to the rates of cut off being the same at each instant in the two cylinders on each side of the locomotive. The solution adopted (fig. 27) has been to transmit by a rocking lever, the motion of the outside valve to the inside valve (*French State, Paris, Lyons & Mediterranean, Tunisian* Railways).

b) *3-cylinder locomotives.*

The inside valve can be driven by suitably conjugating the motions of the two outside valves.

Figure 28 shows in diagram form the way such conjugation of the motion has been employed on the *Alsace-Lorraine, French Est* and *North of Spain* Railways.

A similar result has been arrived at on the *London & North Eastern* Railway by transmitting the motion through horizontal levers in place of rockers (1) figure 29.

The movement of the inside valve is

(1) On some engines (877-880) of the *Madrid to Saragossa and Alicante* Railway, compound locomotives on the Vauclain system with common piston valve to each pair of cylinders are still in use.

(1) Cf. *Engineering*, 17 July 1925.

Railway Mechanical Engineer, August 1926.

Locomotive Cyclopedia of American Practice, 1927 edition, pages 544 and 545.

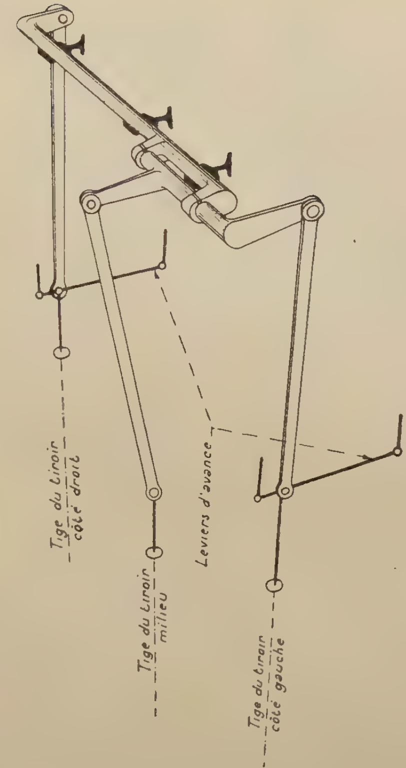


Fig. 28. — Diagram of the conjugated motions of 3-cylinder simple expansion locomotives (*North of Spain, Alsace-Lorraine and French Est Railways*).

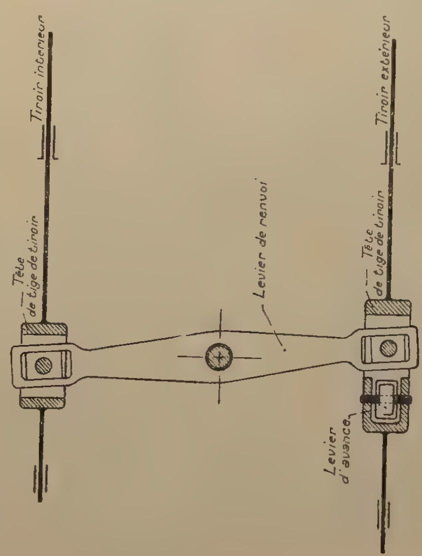


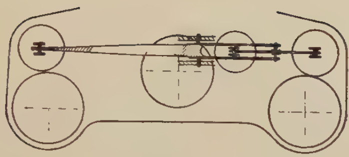
Fig. 27. — Diagram of the conjugated motions of 4-cylinder simple expansion locomotives (*Paris, Lyons & Mediterranean Railway*).

Explanation of French terms in figures 27 and 28 : Levier d'avance = Combination lever. — Levier de renvoi = Rocking lever. — Tête de tige de tiroir = Valve spindle end. — Tige du tiroir, côté droit = Valve spindle, right hand side. — Tige du tiroir, côté gauche = Valve spindle, left hand side. — Tige du tiroir, milieu = Middle valve spindle. — Tiroir extérieur = Outside valve. = Tiroir intérieur = Inside valve.

TABLE F.

Valve events of 3-cylinder simple expansion locomotives 5211 to 5235 of the French Est Railway.

POSITION of reversing gear indicator.	VALUES OF THE EVENTS (per cent of piston stroke). Admission		Cut off.		Pre-exhaust.		Exhaust.		Closing to exhaust.		Lead.		LEAD in millimetres.		MAXIMUM OPENING of steam ports. at admission (in millimetres).		at exhaust (in millimetres).	
	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	F	B	F	B	F	B
A. — Outside cylinders.																		
End of stroke F. .	80	74.5	14.3	18	5.7	7.5	91	93.5	8.8	6.4	0.2	0.1	5		47	48.5	84.5	83
do. B. .	80	73.5	14.5	18	5.5	8.5	90.2	93.5	9.6	6.4	0.2	0.1	5		44.5	45	81	80.5
40 % F. .	40.5	40	39.5	38.5	20	21.5	75	78	24.3	21.4	0.7	0 6	5		12	14.5	50.5	48
40 % B. .	39	41	42	38.5	19	20.5	75	78	24.2	21.3	0.8	0.7	5		12	15	51	48
B. — Inside cylinder.																		
End of stroke F. .	82	75	18.5	13.5	4.5	6 5	92.5	94.5	7.3	5.3	0.2	0.2	4	6	45.5	50.5	86.5	81.5
do. B. .	78	73	17	20.5	5	6.5	93	94	6.8	5.9	0.2	0.1	2	8	44 5	51	87	80.5
40 % F. .	43	38	41.5	39.5	15.5	22.5	74	81.5	25.25	17.25	0.75	1.25	3.5		16.5	15.5	51.5	52.5
40 % B. .	43.5	35	41.5	42	15	23	72.5	82	26.75	16.5	0.75	1.5	3.5		15.5	15	51	51.5



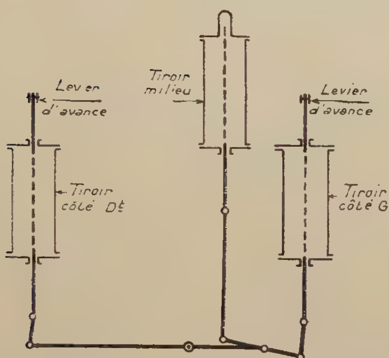


Fig. 29. — Diagram of conjugated motion of three cylinder simple expansion locomotives (*London & North Eastern Railway*).

Explanation of French terms: Vue par bout AV = Front view. — Levier d'avance = Combination lever. — Tiroir milieu = Middle valve. — Tiroir côté G. = Left hand valve. — Tiroir côté D. = Right hand valve. — Vue en plan = View in plan.

not exactly identical (at the same nominal cut off) with that of the two outside valve movements, as will be seen from table F below which gives some values of the phases of the motion of the 5211-5235 locomotives of the French *Est* : the difference is however very small.

2. — Four cylinder compound locomotives.

Each inside valve is driven off the corresponding outside motion.

Figures 30 and 31 show the arrangement used by the *Paris, Lyons & Mediterranean Railway* (on all its recent compound locomotives and by the *Italian State Railways* (on locomotives of group 746) respectively.

On the *Paris, Lyons & Mediterranean,* a combination lever has been retained for each cylinder.

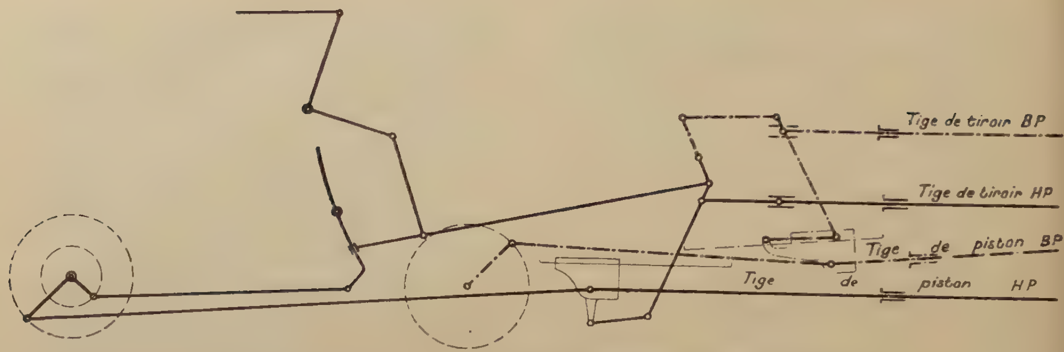
On the *Italian State Railways* no separate combination lever is used for the inside valves. The locomotives of group 746 have piston valves with inside admission for the HP cylinders (which are inside) and with outside admission for the LP cylinders (outside) which has resulted in the case of the LP motion in the return crank being advanced and in the valve spindle being connected to the combination lever below the valve spindle [1].

As a result of the conjugation of the motions, the cut-offs in the HP and LP cylinders are dependent one on the other the relationship being determined by the arrangement and dimensions of the rocking levers.

Tables G and H below, show the corresponding figures obtained for the various phases of the motion at varying cut off positions on the 4-6-2 D locomotives of the *Paris, Lyons & Mediterranean* Railway and the *Italian State Railways* group 746 engines.

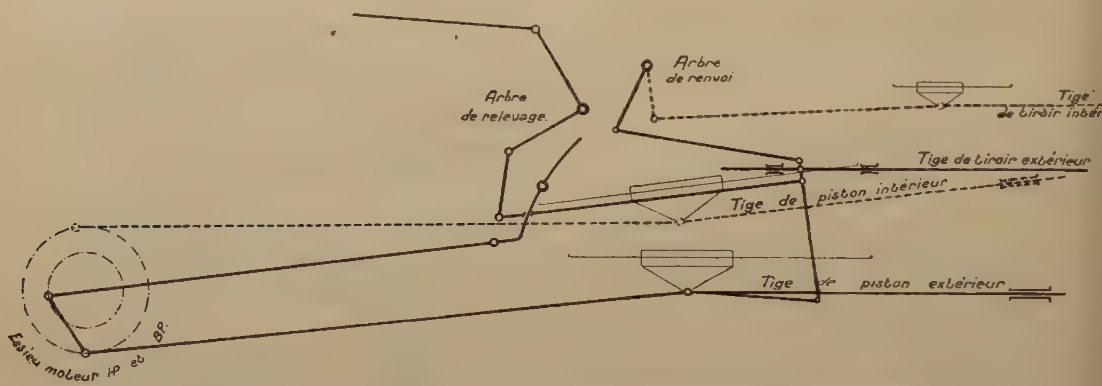
The conjugation of the motions of compound locomotives has undoubtedly the drawback of fixing once for all, the points of cut off in the HP and LP cylinders, but at the same time, it has the advantage, over and above the very important one of a simple and more easily maintained construction, of putting in the hand of an « average » driver, a machine

(1) A similar arrangement is used by the *Reichsbahn* on the standard 4-6-2 superheated compounds (Cf. *Zeitschrift des Vereines deutscher Ingenieure* of the 25 December 1926. « The standard 4-6-2 express locomotives of the Reichsbahn », by Messrs. Fuchs and Wagner.)



A full line ———————— represents the outside motion (HP cylinders).
A chain dotted line -·-·-·-·- — inside — (LP cylinders).

Fig. 30. — Diagram of conjugated motions on 4-cylinder compound locomotives *(Paris, Lyons & Mediterranean Railway).*



A full line ———————— represents the outside motion (LP cylinders).
A chain dotted line ------------- .. — inside — (HP cylinders).

Fig. 31. — Diagram of conjugated motions on 4-cylinder compound locomotives *(Italian State Railways).*

Explanation of French terms in figures 30 and 31 :

Arbre de relevage = Weigh bar shaft. — Arbre de renvoi = Rocker. — Essieu moteur HP et BP = Driving axle HP and LP. — Tige de piston BP = LP piston rod. — Tige de piston HP = HP piston rod. — Tige de piston intérieur = Inside piston rod. — Tige de piston extérieur = Outside piston rod. — Tige de tiroir BP = LP valve spindle. — Tige de tiroir HP = HP valve spindle. — Tige de tiroir intérieur = Inside valve spindle. — Tige de tiroir extérieur = Outside valve spindle.

which can be relied upon to give *quite good* results.

Are conjugated motions to be preferred to separate motions ?

It is a matter of individual preference Some railways such as the *French Est* and the *French Nord* prefer independent motions, whereas the *Paris, Lyons & Medi-*

TABLE G.

Valve events in fore gear of the 4-cylinder compound 231 D locomotives of the Paris, Lyons and Mediterranean Railway.

POSITION of the single reversing gear indicator.	VALUES OF THE EVENTS (per cent of piston stroke).												LEAD in milli-metres.	MAXIMUM OPENING of steam ports.	
	Admis-sion		Cut off.		Pre-exhaust.		Exhaust.		Closing to exhaust.		Lead.			at admis-sion (in milli-metres).	at exhaust (in milli-metres).
	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.			
A. — Outside cylinders (H. P).															
3	29.3	30.7	39.5	36.5	31.2	32.8	68.9	70.2	29.8	28	1.3	1.8	6	10	48
4	39.5	40.5	35.5	31.9	25	27.6	79	81.8	20.1	17	0.9	1.2	6	13.2	51.2
6	60.7	59.3	24	22.8	15.3	17.9	87	89	12.6	10.5	0.4	0.5	6	23.3	61.3
end	80	79.5	12.4	11.7	7.6	8.8	93.7	94.9	6.1	4.9	0.2	0.2	6	52	90
B. — Inside cylinders (L. P.).															
3	37.4	42.5	37	32.1	25.6	25.4	80.8	81.8	18.5	17.6	0.7	0.6	6	14 6	52.6
4	50.8	53.5	19.9	16.2	19.3	20.3	84.9	86.4	14.7	13.2	0.4	0.4	6	20.3	58.3
6	73.6	70.8	16.3	17.4	10.1	11.8	91.8	93	7.9	6.8	0.3	0.2	6	38.4	76.4
end	89	85	6.7	8.8	4.3	6.2	95.9	97	4	2.9	0.1	0.1	6	76.8	114.8

TABLE H.

Valve events in fore gear of the 4-cylinder compound group 746 locomotives of the Italian State Railways.

POSITION of the single reversing gear indicator.	VALUES OF THE EVENTS (per cent of piston stroke).												LEAD in millimetres.	MAXIMUM OPENING of steam ports.	
	Admission		Cut off.		Pre-exhaust.		Exhaust.		Closing to exhaust.		Lead.			at admission (in millimetres).	at exhaust (in millimetres).
	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.	Front port.	Back port.			
A. — Outside cylinders (L. P.).															
32	58.8	58	20.9	20.8	20.3	21.2	84.4	85.2	13.3	12.2	2.3	2.5	11	24	...
42	69.8	69.3	15.7	15.8	14.5	14.9	89.3	89.8	9.4	8.7	1.3	1.5	11	34	...
58	82	82.2	9.9	9.6	8.1	8.2	94.4	94.3	4.9	4.9	0.7	0.2	11	58	...
74	90.2	91	5.6	5.2	4.2	3.8	97.3	97.2	2.5	2.5	0.2	0.2	11	102	...
B. — Inside cylinders (H. P.).															
32	31.2	33	36.8	35.5	32	31.4	74.7	74.7	23.6	22.9	1.7	2.2	7	12	...
42	42.6	42.6	31.6	31 2	25.8	26.2	79.5	79.7	19.3	19	1.2	1.3	7	17	...
58	60.6	57.8	22.2	23.9	17.2	18.3	86.2	87	13.1	12.2	0.7	0.8	7	29	...
74	76.7	71	13.5	17.7	9.8	11.3	91.8	93	6.9	6.8	0.3	0.2	7	56	...

terranean consider the conjugated motion to be more satisfactory.

B. —Special designs of motions.

I. — Poppet valve gears.

Poppet valve gears are at the present time being tried on many railways.

a) *Oscillating cam gear* (cam shaft driven by Walschaerts gear).

The valve events are of course those obtained with an ordinary Walschaerts gear.

Lentz (or Paxman or Dabeg) gears are being tried at the present time :

— on 11 locomotives of the *Madrid to Saragossa and Alicante* Railway,

— on five 4-8-4 compound locomotives on the *Paris, Lyons & Mediterranean* Railway, and

— on one 4-6-2 compound locomotive on the *Paris-Orleans* Railway.

In the early applications the cams operated the valve spindles directly (1). This arrangement has since been given up; the spindles are now operated through intermediate levers (2) which avoid any bending thrust on the valve spindles and give a much quicker opening of the valves.

b) *Poppet valves with rotary cams.*

The rotary cam poppet valve gears now undergoing test are of the *Caprotti, Dabeg* and *Renaud types*. With the *Caprotti* and *Dabeg* gears the compression is completely independent of the admission, and constant compression, constant lead, and constant pre-exhaust are obtained. This is not so with the *Renaud* gear which however gives compressions at very early cut offs which are perfectly satisfactory.

The following table compares the main features of the *Caprotti* and *Renaud* gears.

The *Caprotti* gear has been fitted on the *Italian State* Railways to ten 2-8-2 4-cylinder compound locomotives, thirty 2-6-2 4-cylinder simple expansion locomotives, and to thirty-one 2-8-0 2-cylinder simple expansion locomotives : these railways are fitting 200 other locomotives with it.

This type of gear is also being tested on the *North of Spain, Paris, Lyons & Mediterranean* and by the *Mediterranean* Railways.

The *Dabeg* gear is being fitted to several locomotives of the *Madrid to Saragossa and Alicante* and of the *Paris, Lyons & Mediterranean* Railways.

The *Renaud* gear is being tested on a 2-8-2 2-cylinder simple expansion locomotive of the *French State*.

II. — Limited cut off.

Limited cut off (1) is not used in any of the countries given in appendix II. The value of it is not clear however current practice being to expand the steam.

III. — Uniflow motion.

Uniflow motion, such as the *Stumpf*, tried out some time ago (2) has just been

(1) Cf. The *Railway Engineer*, May 1926.

(2) Cf. *Locomotive Cyclopedia of American Practice,* 1927 edition, page 538.

Chaleur et Industrie, November 1928, p. 528.

(1) Cf. *Railway Age*, 30 July 1927. Fuel as opposed to limited cut off. Discussion on the advantages resulting from limiting the cut off from the point of view of the efficiency and economy of working of the locomotive, by H. J. VINCENT.

(2) Cf. *Bulletin of the International Railway Congress Association*, May 1910, p. 2207.

—	*Caprotti gear* [1].	*Dabeg gear.*	*Renaud gear.*
Cam shaft drive	1 cam shaft per cylinder or per pair of cylinders driven by the driving wheels at the same angular speed of rotation.		The cam shafts are d[illegible] by the driving w[illegible] at half the ang[illegible] speed.
Valves.	1 steam and 1 exhaust valve at each end of each cylinder that is 4 valves per cylinder.		
Method of altering valve events.	The cam shaft, which cannot move longitudinally carries for the steam valves 2 cams one of which controls the opening and the other the closing of the two steam valves of the same cylinder the relative position of these two cams being variable by altering the reversing gear. For the exhaust one cam controlling both the opening and closing of the two corresponding exhaust valves. The angle of this cam being altered to the correct value when the engine is reversed.	The cam shaft can be moved longitudinally by the reversing gear whereby the cams of the desired profile for the particular cut off chosen can be brought in line with each of the valve spindles the same cam controlling the opening and the closing of the two corresponding valves (admission or exhaust) of the same cylinder. ...	The cam shaft whi[illegible] not free to move [illegible]gitudinally consis[illegible] one cam with two [illegible]jections for each o[illegible] four valves. The profile of each [illegible] is made variabl[illegible] a special link d[illegible] operated by the re[illegible]ing gear.
Results obtained	Preadmission, Pre exhaust, Exhaust } constant. And as a result : Compression : constant.	Preadmission, Pre exhaust, Exhaust } constant. And as a result : Compression : constant. A variable exhaust and consequently compression in accordance with a formular decided upon beforehand can be easily provided : all that is needed for this is to give the exhaust cams (for constant compression the surface of the cam is that of a cylinder parallel to the cam shaft) the desired form.	The phases of admi[illegible] and exhaust are i[illegible]dependent.

[1] For particulars of the Caprotti gear, cf. :
Rivista Tecnica delle Ferrovie Italiane, June 1921, page 152; *Railway Mechanical Engineer*, March 1927.
The Railway Engineer, November 1927, page 398 and March 1928, page 95.

applied to the Winterthur 60 kgr. per cm² (850 lb. per square inch) locomotives (1).

So fas as we are aware this type of motion has not been tested recently on locomotives of usual design.

C. — CONCLUSIONS.

a) Long valve strokes improve the efficiency of locomotives and enable them to run more freely at high speeds;

b) The conjugation of the motions has substantial advantages from the point of construction and maintenance; it is especially of value for simple expansion locomotives;

c) Poppet valve gears are being increasingly used, at least for trial.

CHAPTER VI.

Draft and Exhaust (2).

I. — Present position.

The table, appendix VI, gives particulars of the blast pipe arrangements used up to the present by most of the administrations given in appendix II.

It should be noted that *variable* blast pipe tops [cone type on the Nord, clover leaf type on the P. L. M. (3)] are preferred by all the French, and by some Spanish railways.

Furthermore, two new types of blast pipe layout are reported : the *Kylälä* and the *Gallez*.

II. — Improvements in the layout of the blast pipe.

1. Kylälä exhaust.

The Kylälä blast pipe (fig. 32) is a fixed blast consisting in the main of five Kylälä cones (fig. 33) arranged one above the other between the blast pipe top and the chimney.

Tested by most of the railways, it appears to have been adopted only by the *North of Spain* Railway which has fitted it to various classes of engines (the *French State, Est,* and the *Paris, Lyons & Mediterranean* Railways have given up its use as it is not variable, the *French State* finding furthermore, that it gave inferior results to those obtained with the clover leaf blast pipe top).

2. Blast pipe arrangements derived from the Kylälä

The *Paris-Orleans* Railway has developed two types of blast pipe derived from the Kylälä.

— the *IK/IC pattern* (fig. 34) utilising a Kylälä cone K and a cylindrical petticoat C arranged one above the other between the blast pipe top and the chimney.

— the *IK/T* (fig. 35) similar to the former but in which the whole unit formed by the chimney and the cylindrical petticoat pipe has been replaced by a venture tube T of such form and size that a definite vacuum could be formed at the choke of this tube.

(1) Cf. *Bulletin of the International Railway Congress Association,* January 1929, p. 75.

(2) The question of the draft and of the exhaust was examined in detail at the 1900 Congress (*Bulletin* of December 1899, p. 1554; April 1900, p. 563; June 1900, p. 1981; November 1901, p. 2509). It was again considered at the 1922 Congress (*Bulletin* of September 1921, p. 1192; October 1921, p. 1532 and April 1922, p. 657).

(3) Cf. *Revue Générale des chemins de fer.* « Clover leaf blast pipe tops on the *Paris, Lyons & Mediterranean* Railway », by Mr. M. Japiot.

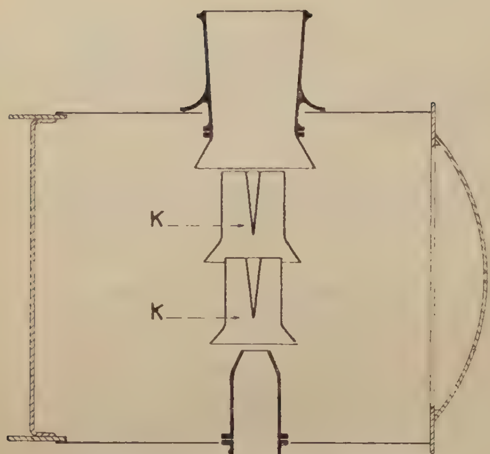


Fig. 32. — Kylälä exhaust arrangement.

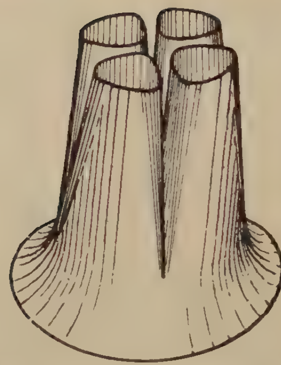


Fig. 33. — Kylälä intermediate cone.

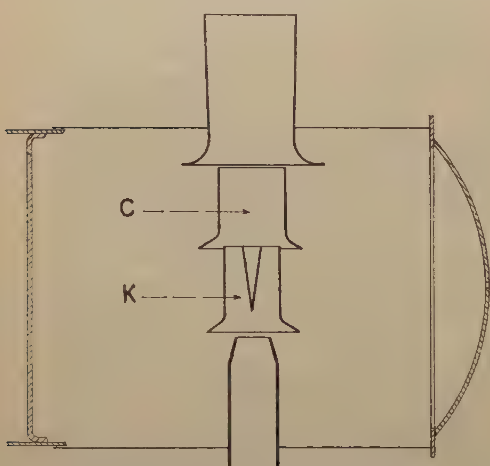


Fig. 34. — 1K/1C exhaust arrangement.

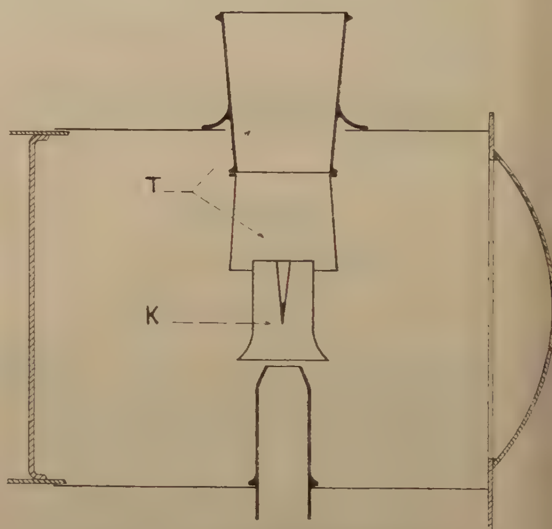


Fig. 35. — 1K/T exhaust arrangement.

If desired, the exhaust can be made variable by means of small bars carried on a holder which can be moved in relation to the top of the blast pipe.

These two arrangements of blast pipe and chimney have proved to be an improvement on the other designs (Nord, cone — P. L. M., clover leaf) tried for comparison.

For details of these tests and the results obtained, we would refer to the article published in the *Revue Générale des chemins de fer* (August and September 1928) by Mr. Chapelon, only the characteristic curves (fig. 36) of the improved Kylälä arrangement taken on a 4-cylinder compound superheated *Pacific*, and on a 2-cylinder simple *Pacific* being reproduced here (the *very low* values of the cylinder back pressures will be noticed).

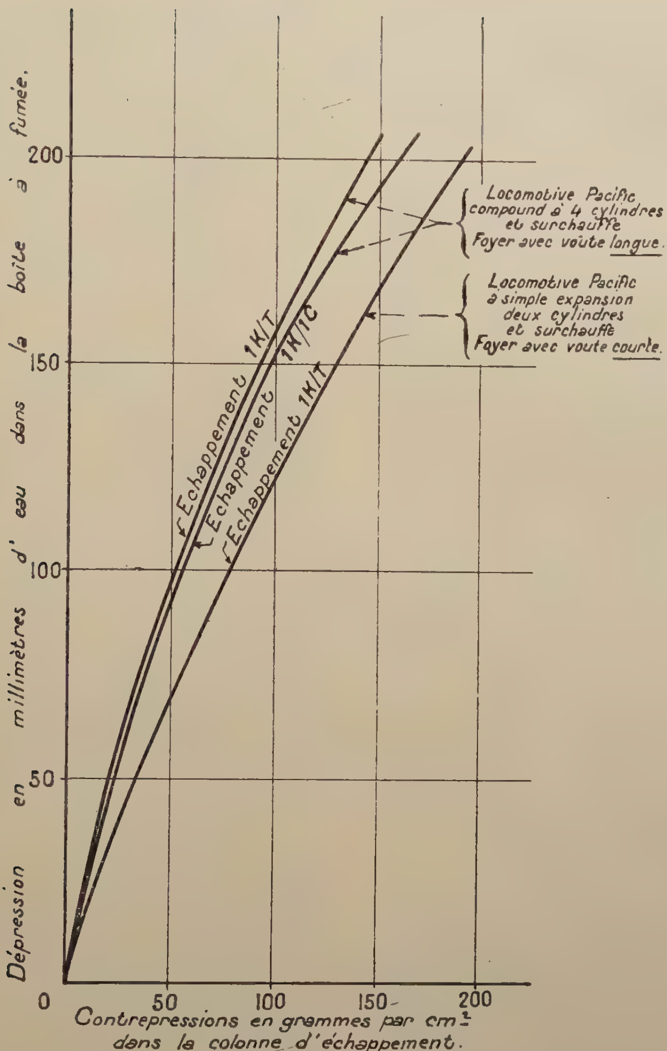


Fig. 36. — Characteristic curves obtained with 1K/1C and 1K/T. exhaust designs.

Explanation of French terms : Dépression en millimètres, etc. = Smoke box vacuum in millimetres of water. — Contrepression en grammes, etc. = Back pressure in grammes per cm² in the exhaust pipe. — Échappement = Exhaust. — Locomotive Pacific compound à 4 cylindres, etc. = 4-cylinder compound superheated Pacific locomotive, long brick arch. — Locomotive Pacific à simple expansion, etc. = 2-cylinder simple superheated Pacific locomotive, short brick arch.

The tests on the *Paris-Orleans* have also shown the value of *lengthening as much as possible the brick arch in the fire box.*

The IK/IC and IK/T blast pipe arrangements have been fitted to about a hundred *Paris-Orleans* locomotives and are being tested on the *Midi* and the *Paris, Lyons & Mediterranean* Railways.

It is of interest to note that in this connection the *Paris, Lyons & Mediterranean* Railway carried out tests with the variable clover leaf top combined with the Kylälä arrangement, the three-wing clover top being of course replaced by a « cross » giving 4 jets instead of 3.

This new design of exhaust fitting, whilst having a rather better characteristic [1] than the ordinary clover leaf top, has not been retained owing to the fact that it resulted in the smoke beating down on to the boiler.

3. Clover leaf blast in conjunction with a petticoat pipe.

Tests carried out on the *French Est* with various designs of blast pipe arrangements, on engines whilst standing (by passing steam at different pressures through the exhaust passages and reading the pressure at various points in the smoke box) have shown *that petticoat pipes ought to be used.*

The *French Est* in consequence, is making tests with petticoat pipes on thirty 2-8-0 goods engines fitted with the clover leaf blast pipe top.

4. Gallez blast pipe.

This is a fixed blast pipe top (fig. 37) used on the *Aragon* Railways where it has given better results than the Kylälä.

III. — New designs of blast pipes : turbo-exhausters.

The *Paris, Lyons & Mediterranean* Railway fitted for trial purposes a 230 C type compound superheater locomotive with a

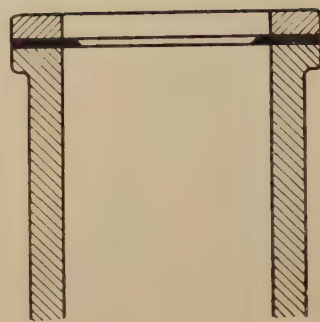


Fig. 37. — Gallez exhaust arrangement.

turbo-blower made by the *Rateau Company.*

The apparatus consisted of a helical bladed exhauster driven by a turbine driven in turn by exhaust steam from the cylinders.

The results obtained were very similar to those got with the clover leaf blast pipe usually fitted to the 230 C class locomotives, but did not show any improvement. It must be noted however, that the turbo-exhauster tested, had been designed to produce a vacuum definitely greater than that required to work the test trains : the rate of combustion attained was also much below that expected. Under these conditions, the dimensions of the apparatus were quite different from those which would have given the optimum result. No definite conclusion can therefore be drawn from these tests as to the relative values of the clover leaf top and the turbo-exhauster.

In this connection the tests carried out by Mr. *W. F. M. Goss* [1] should be noted, the conclusions of which may be summarized as follows : the turbo-exhauster has a characteristic curve which is better

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(1) On the diagram whereon the back pressures are shown as abscissæ and the drafts as ordinates.

(1) Cf. *Railway Age*, 11 June 1927.

than that of the ordinary blast pipe arrangement, but on the one hand the wheel of the fan undergoes very rapid wear owing to the rubbing action of the solid particles carried over in the combustion gases and on the other the efficiency of the turbine falls off quickly in service owing to accumulations of oil on the blades from the exhaust steam (the author considered however these drawbacks could be overcome.

IV. — Special devices for preventing smoke from beating down on the boiler.

Various fittings have been tried, the most interesting of which are the following :

1. *German Railways design* of two plates parallel to the longitudinal plane of the engine, fitted on each side of the smoke box.

This fitting has been tested, after some alterations in details, on the *Alsace-Lorraine* and on the *Paris-Orleans* on which its application is being extended : it is undergoing test on the *French Est*.

2. *Prandlt device* [1] (paraboloid surface of the front of the smoke box).

The class 241 A locomotives of the *Paris, Lyons & Mediterranean* Railway have been fitted in this way.

The *French Est* which has tried it, obtained quite good results : it has not however, fitted it generally, owing to the way it fouls the adjacent lines when the smoke box door is open.

3. *Stream lining* the parts (chimney and domes) projecting above the smoke box and boiler barrel.

The *French Est* has tried this method with some success.

(1) Cf. *Zeitschrift des Vereines deutscher Ingenieure* of the 24 March 1923.

Besides permanent fittings, such as those mentioned above, which are intended to impress on the smoke on leaving the chimney a suitable direction, mention must be made of the way *blowers* can be used to clear *momentarily*, the field of *visibility*. (The *French State Railways*, in order to get rid of the smoke more quickly than is possible with the ordinary blower steam valve has fitted the 231-000 and 231-500 locomotives with a supplementary steam supply with a mushroom valve operated by a lever giving a very rapid opening in case of urgency).

V. — CONCLUSIONS.

Improvements in the efficiency of the blast pipe and front end arrangement have been the object of many trials : good results have been obtained by using multiple cones and petticoat pipes.

CHAPTER VII.

Miscellaneous questions.

A. — Compounding [1].

Present position of the subject.

None of the Administrations enumerated in appendix II has since 1922 carried out *methodical* tests with a view to comparing simple and compound locomotives.

Many tests have been made, but the locomotives being tested, apart from the manner of using the steam, have not been *identical*.

The table, appendix VII, gives as regards the principal administrations mentioned

(1) This question was considered at the Rome Congress 1922. See *Bulletin of the International Railway Congress Association*, April 1923, page 292.

above as on the 1 January 1922 and 1928, the number of saturated steam and superheated steam simple and compound locomotives.

B. — Improvements in combustion.

Combustion chambers.

Several railways have endeavoured to improve the efficiency of the boilers by using *combustion chambers*.

This arrangement is used on the :

— *Andalusian* Railways, on the 4-8-2 locomotives Nos. 4301 to 4310.

— *North of Spain* Railway on the 4-8-2 (1) No. 4600 locomotives,

— *French Est* Railway on a trial 4-8-2 locomotive No. 41001.

— *Paris, Lyons & Mediterranean* Railway on the 4-8-2 (2) locomotive No. 241 A.

— *Italian State* Railways on the 2-8-2 (3) locomotives of group 746.

The *Paris-Orleans* Railway is making a trial on a 4-6-2 locomotive, by shortening the tubes.

The Companies concerned report that they are satisfied with the results.

C. — Devices for improving the circulation of the water in the boilers.

1. Nicholson thermic syphons (4).

This device is undergoing test on a 4-6-2 locomotive of the 690 class with copper firebox on the *Italian State Railways*.

It is also about to be tested on the *Paris-Orleans* Railway.

2. Arch tubes (1).

Brick arches with water tubes (arch tubes) are being fitted to all the locomotives wih copper fireboxes on the *French Est* Railway.

They are undergoing trial on the *Andalusian* Railways (on 10 locomotives 4301-4310 with copper fireboxes, of the 4-8-2 type and on the *North of Spain* locomotives with copper fireboxes, No. 4600, 4-8-2 type and No. 4500, 2-8-2 type).

The *Paris-Orleans* Railway has also tried arch tubes on 10 locomotives 7101-7349 of the 2-8-0 type with steel fireboxes, but had to abandon the design experimented with for the following reasons : fire more difficult to manage owing to the arch being lower, repairs to the firebox more difficult to do, leaking of the tubes in the tube plate (2), and finally no saving of fuel.

D. — Regulators.

1. New designs of regulators.

a) *Lejeune regulator* with multiple valves. This regulator consists of 8 or 9 small independent mushroom valves arranged in a circle and which although opened by a single lever, are lifted one after the other off their seats when the regulator handle is moved.

The Lejeune regulator has been tested on the *North of Spain*, the *Alsace-Lorraine* and the *Paris, Lyons & Mediterra-*

(1) Cf. *Zeitschrif des Vereines deutscher Ingenieure*, August 1925.

(2) Cf. *Revue Générale des chemins de fer*, February 1926.

(3) Cf. *Rivista Tecnica delle Ferrovie Italiane*, April 1924.

(4) Cf. *Locomotive Cyclopedia of American Practice*, 1927 edition, page 272.

(1) Cf. *Locomotive Cyclopedia of American Practice*, 1927 edition, page 276.

(2) On the *French Est*, it was found possible to keep the tubes tight by suitably expanding them and by giving them a marked curvature to take up expansion.

nean Railways. The two latter Companies have not found any marked superiority over the regulators in use and have given it up.

b) *Schmidt and Wagner* regulators with main and pilot valve [1] (*Andalusian* Railways;

c) *Restucci regulator* which acts not only as a regulator, but also as a steam drier by wire drawing through a large number of narrow orifices (*Catalan and Smyrna to Cassaba* Railways).

2. Regulators fitted after the superheat.

a) *Babcock and Wilcox regulator.*

This is a regulator using a piston valve, the steam tightness being assured by four rings.

The *North of Spain* Railway which has made experiments with this type of regulator on its 4301-4316 locomotives, experienced at first some trouble owing to the excessive expansion of the rings which caused the piston rod to stick.

b) *Multiple valve (in line) regulator of the Superheater Corporation* [2].

This regulator is only mentioned as a reminder, none of the Companies given in Appendix II having tried it.

E. — Steam driers on superheater locomotives.

The *Catalan* and the *Smyrna to Cassaba* Railways are the only railways who have made tests with steam driers on superheater locomotives (the Restucci valves mentioned above in § D); the *Catalan* Railways were not able to record any fuel economy.

(1) Cf. *Zeitschrift des Vereines deutscher Ingenieure*, 25 December 1926, page 1731.

(2) Cf. The *Railway Engineer*, June 1927, page 239; the *Engineer*, 23 March 1928, p. 330.

F. — Soot blowers.

Different companies have carried out, or are doing so, tests with fittings for cleaning the smoke tubes whilst running (single blowers at the back of the fire box: *Diamond* and *Dalmar*, two blowers arranged symetrically on each side of the locomotive : *Superior S. A. F.* and *Wolfgang*) [1].

From the results obtained on the *Paris, Lyons & Mediterranean*, and the *North of Spain* Railways, the *Diamond* blower does not entirely suppress tube cleaning at the depots. (The *Paris, Lyons & Mediterranean* Railway has not continued the use of this type of blower, whereas the *North of Spain* fits it to engines having fireboxes of moderate length.)

The *S. A. F.* blowers have given good results on the *Paris-Orleans* Railway which, however, is not fitting them generally, owing to the high first cost.

G. — Boosters.

No test has been carried out by any of the Companies given in appendix II.

H. — Use of special steels.

1. Special steels used in the gear to lighten the moving parts.

a) *Class D steel* [1] *heat treated.*

The *French Nord* Railway uses normally D steel heat treated either by the « a »

(1) The *Wolfgang* fitting, the blowers of which clean the smoke box tube plates, can only be fitted to locomotives that are not superheated.

(1) D steel ingots are made from Martin, electric or crucible steel only.

Minimum characteristics. Breaking load, 48 kgr. per mm² (30.48 Engl. tons per square inch); elongation at fracture, 23 %.

method (the usual one) or by the « b » method.

— Heat treatment « a ».

Quench at 900° C. (1 652° F.) in water at 15° C. (59° F.).

Reheat to at 600-650° C. (1 112-1 202° F.) and cool off in the air.

The following minimum characteristics are specified on the *French Nord* when ordering parts in D steel having received the « a » treatment :

Load at the elastic limit 35 kgr. per mm² (22.22 Engl. tons per square inch).

Load at fracture 60 kgr. per mm² (38.10 Engl. tons per square inch).

Elongation at fracture, 17 %.

— Heat treatment « b ».

Quench at 900° C. (1 652° F.) in water at 15° C. (59° F.).

Reheat to 470-500° C. (878-932° F.) and cool off in the air.

There is no specification giving the characteristics of D steel when heat treated in this way.

The *French Nord Railway* is satisfied with a Brinell hardness test in parts so treated. The diameter of the impression of a 10 mm. ball under a 3 000 kgr. load is to be between 3.9 and 4.2 mm.

The minimum characteristics corresponding to tests made as a matter of interest were as follows :

Load at the elastic limit 42 kgr. per mm² (26.67 Engl. tons per square inch).

Load at fracture 70 kgr. per mm² (44.45 Engl. tons per square inch).

Elongation at fracture 12 %.

The *French Nord* Railway only allows heat treatment to be carried out at the main workshops.

b) *Special nickel and chrome nickel steels.*

The *French Est* uses the following special steels on some classes of engines :

CLASS.	NICKEL.	CHROMIUM.	PHOSPHORUS.	TENSILE TESTS. Metal quenched and reheated.		DROP TEST on notched bars. Metal quenched and reheated.	PURPOSES FOR WHICH USED.
	minimum %	minimum %	maximum %	Minimum strength in kg/mm².	Minimum Elongation %	Minimum Resilience in kilogrammetres per cm² of section.	
SB	2	...	0.04	48	22	35	Excentric rods and combination levers.
SD	2.5	0.5	0.04	60	18	25	Pins.
SF	2.5	0.5	0.04	75	13	15	Combination levers and radius rods.
SH	3.5	1 25	0.04	90	10	10	Keys.

The manufacture of parts made from these steels is only carried out at the Company's works at Epernay; as a special case, depots having case hardening furnaces are permitted to harden motion pins of S. D. steel : they are also allowed to

straighten motion parts when they are accustomed to do this work at the shed.

The saving in weight due to the use of special steels is not less than 30 %.

The *French Est* Railway is considering the use of nickel and nickel chrome steels for all reciprocating parts, both in the valve motion and driving gear.

2. Special steels used in the frame and the boiler in order to reduce the dead weight of the engine.

The *Paris, Lyons & Mediterranean* Railway is about to try nickel steel for boiler [1] plates and axles.

3. Special steels for springs.

The *French Railways* use for the actual *springs* R and S steels which have to confirm with the bend, flexibility, reverse bending and shock tests of the standard specifications.

The *French Est* and the *Paris, Lyons & Mediterranean* Railways also use for the spring links *cast manganese steel* (manganese content of from 12 to 14 %).

I. — Use of special light alloys.

The *French Est* uses light aluminium alloys having the following characteristics :

Class.	Constituents.	Percentage of constituents.	Tensile tests.		Chemical analysis.
			Minimum breaking strength, kilogr./mm².	Minimum elongation, per cent.	
A_1.	Aluminium. Copper.	92 8	10	...	The copper content should be between 7.5 and 9 %. The total impurities should not exceed 2.5 %, 1.5 of which at most being iron.
A_2 (Alpax).	Aluminium. Silicon.	87 13	17.5	4	...

Light aluminum alloys are used on the *French Est* for various parts, such as : piston guides, oil boxes, slide valves with a steel frame (as a trial), various guides and brackets (on the 4-8-2 type locomotive type No. 41001).

The saving of weight gained by using these alloys should be from 50 to 60 %.

J. — Locomotive lighting.

As a rule, *paraffin* or *oil* is used for lighting.

Electric lighting by *turbo-generator* as adopted by the *French Nord*, is being tested to a more or less wide extent on various other railways (*Andalusian, Aragon, North of Spain, Alsace-Lorraine, French Est, Paris, Lyons & Mediterranean* and *Paris-Orleans* Railways). The capacity of the sets in use (*Pyle National, Sunbeam, Rateau, Société Alsacienne de Constructions Mécaniques*) is as a rule 500 watts; the *Paris-Orleans* however considers this capacity too great and is about to make trials with sets giving 150 watts

(1) Cf. chapter I, C.

only, besides which these sets will also be cheaper.

The *Italian State* Railways are extending the fitting of electric light supplied from accumulators.

Electric light is undoubtedly attractive, but requires relatively expensive equipment.

As a consequence, some companies are considering the use of *acetylene* which gives a much better light than is possible with paraffin or oil.

The *French Est* (on its new engines) and the *Paris-Orleans* Railways, use acetylene for lighting the driver's cab.

The *Paris, Lyons & Mediterranean* Railway is making trials of this illuminant, not only for the cab, but also for the head and tail lamps.

The following comparative figures have been supplied by the *Paris-Orleans* with regard to lighting by oil and by electricity :

—	Lighting by oil or paraffin (for 1 engine).	Lighting by ele tricity (for 1 engine).
	Francs:	Francs:
Cost of fitting	1 000 à 2 000	13 800
Cost of running (550 hours per annum) .	0.65 per hour.	1.26 per hour.
Maintenance	750 per annum.	225 per annum.

K. — Wheel flanges and rail lubrication.

In order to reduce the wear of tyre flanges and that of rails on the small radius curves of which there are large numbers in hilly country, many Companies have endeavoured to lubricate either the flanges of the wheels or the rails.

1. Flange lubrication.

a) *Apparatus carried on the locomotive.*

The principal types of flange lubricators are :

— on the one hand the *tube oilers with felt plug* and the *oilers with a felt wick* with continuous but not adjustable feed,

— on the other, the *Buclon lubricators* the feed of which is relative to the speed (no feed during stops).

An article on these three types of oilers appeared in the June 1928 number of the *Revue Générale des chemins de fer*, page 472; the Buclon lubricator was also dealt with in the January 1928 *Bulletin of the International Railway Congress Association*, page 11.

As regards results obtained, the *Midi* Railway reports that the use of tube oilers has reduced the wear of flanges by half : in consequence all locomotives liable to work over curves of less than, or equal to 300 m. (15 chains) are being fitted with these oilers.

The *Paris, Lyons & Mediterranean* Railway reports that on its system, the Buclon lubricators (the oil consumption with which is 0.5 gr. per lubricator per kilometre [0.454 dram per mile], that is to say 1 gr. per engine and per kilometre

[0.908 dram per engine and per mile]) has made it unnecessary to change over the leading and trailing coupled wheels between two liftings, this change only being done at each lifting (the wear per 100 000 km. run, of the flanges of the leading wheels has fallen from 30 to 10 mm.).

The Company is satisfied with the results given by the *Buclon* lubricator with which more than 250 engines will be fitted by 1929.

b) *Apparatus fitted to the track.*

The only apparatus of which we have knowledge is the *Derrick* used by the *Norfolk & Western* Railway (1).

2. Lubrication of the rails.

The *Paris-Orleans* Railway at the present time is making trials with an « *automatic rail lubricator* ».

This apparatus is composed of the following details (2):

— A container holding a certain volume of oil under pressure;

— A compressed air atomiser which produces an emulsion of oil under pressure for lubricating the rail;

— An arrangement of pipes by which the oil emulsion under pressure is directed from both sides of the locomotives respectively onto the vertical inside faces of the rails. The ends of these pipes near the rails are fitted with a cone arranged to project the emulsion of oil under pressure and set so that under no circumstances can the oil be thrown on to the top face of the rail, that is to say, on to the running surface where the presence of oil would be a drawback (slipping, and difficulty with the brakes);

— An *automatic* control gear, by which *the lubrication of the rails is only done when the locomotive runs onto a curve* and is limited exclusively to the inside *vertical face of the outer rail of the curve*, that is to say the rail furthest from the centre of the curve.

(1) Cf. *Railway Age*, 14 may 1927, p. 1449. *Bulletin of the Internaional Railway Congress Association*, August 1927, p. 703.

(2) Cf. *Revue Générale des chemins de fer*, May 1929.

L. — Balancing of the moving parts of locomotives

The rules followed for balancing the moving parts are in all cases (1) very different as between one company and an other :

— balancing completely the rotating parts and ignoring the others (*French Nord* for its 4-cylinder locomotives and the *Paris, Lyons & Mediterranean* Railway);

— balancing the whole of the rotating parts and a part of the alternating parts so as to limit the additional load on the rail to a certain amount (2) 1 500 kgr. (3 307 lb.) on the *French State* and 1 200 kgr. (2 645 lb.) on the *Paris-Orleans* Railways);

— balancing the whole of the rotating parts and a specified percentage of the

(1) Cf. *Bulletin of the International Railway Congress Association*, August 1922, p. 1126. Report of the discussion on question VI at the Rome Congress (1922).

(2) The percentage of the reciprocating masses balanced is of course variable (on the *Paris-Orleans* when the hammer blow is limited to 1 200 kgr. (2 645 lb.) this percentage is as a rule of the order of 10 %).

reciprocating masses (this percentage is fixed at 30 % on the *French Nord* for the 2-cylinder locomotives and at 33 % for the *Madrid to Saragossa and Alicante* Railways);

— balancing the reaction as completely as possible (the *French Est* which has adopted this method has laid down that the values of the vertical reactions due to the counterbalance weights is not to exceed 80 % of the unsprung weight of the coupled wheels).

APPENDIX I

Detailed list of questions relating to question VI. [1]

CHAPTER I.

Increased boiler pressure.

1. — Recognised standard boiler pressure for superheated locomotive boilers built since 1922 (simple and compound expansion locomotives being shown separately).

2. — Are you considering any increase in the pressure in use at present *without changing the appearance of the present design of boiler?* [2].

If you have made any tests on these lines, please give information on the following points :

a) General characteristics and number (per class) of the locomotives with increased pressure.

State if the boilers of the locomotives in question are, or are not, the old boilers altered;

b) Special features necessitated by the increased pressure (attach any cognate drawings);

c) Tests carried out and results obtained (superheat temperature, fuel consumption...);

d) Effect of the higher pressure upon :

α — Repair and frequency of periodical examinations of the boilers;

β — Time locomotives are out of service;

γ — Cost of repairs.

3. — Conclusions.

CHAPTER II.

Superheating.

A. — *Increase in the superheat temperature.*

1. — Indicate the lines of investigation you followed with a view to improving the superheating of locomotives.

In particular information should be given on the three following points :

a) Temperature of the superheated steam (relatively to that of steam at the boiler pressure) obtained up to recent years;

b) α — Temperature of the superheated steam (relatively to that of steam at the boiler pressure) desired;

β — Reasons that led to this latter value being adopted.

c) Lines of investigation of the enquiry.

2. — Tests carried out with a view to improving the superheat and results obtained.

a) Give particulars of the various trials carried out in order to increase the superheat, and give the results obtained.

Describe in particular for each type

(1) In order to shorten the text, the examples of the tables and the appendices given in the questionnaire have not been reproduced.

(2) Consequently water tube boilers and high pressure boilers are not included.

of locomotive concerned the effect of each of the alterations on the superheat temperature and on the fuel consumption.

Attach all useful relative drawings and graphs;

b) Summarise the report [*a*) above] by drawing up a table I like the model attached to this questionnaire. (Please confirm to the requirements given in the notes.)

Insert in addition, on table I, the locomotives on which the temperature of the superheated steam is already at least 325 C. (617° F).

3. — Conclusions.

Conclusions, *relative to the improvement of the superheat,* drawn from the tests you have carried out. What are, in particular, your conclusions on the following points (attaching all useful relative drawings and papers) :

a) Is it of value to have the highest possible superheat temperature ?

b) Essential ratios to be observed as between the various parts forming the nest of boiler tubes and flue tubes;

c) Best arrangement of the smoke tubes;

d) Best arrangement of the superheater (superheater with elements placed in large or small smoke tubes — shape of the elements in the tubes — shape of the element supports);

e) Best arrangement to use for the saturated and superheater headers.

B. — *Best layout of the superheater and of those parts the working of which is connected with the application of superheating.*

This question was treated at length at the 9th Session of the Congress (Rome 1922). See on this subject, the following numbers of the *Bulletin of the International Railway Congress Association :*

Preparatory documents :

1st report, by Mr. Lacoin (Bulletin of September 1921, page 1157);

2nd report, by Mr. Churchward (Bulletin of October 1921, page 1527);

Special Reporter : Mr. Lacoin (Bulletin of April 1922, page 653).

General report of the discussion at the Congress and final summary :

Bulletin of April 1923, page 292.

Please, therefore, when sending in any information, to refer to the documents already published in the Bulletins quoted.

Please also state when replying to each question the alterations made, if any, in consequence of the increase in superheat temperature.

1. — Superheater.

In this connection it is a question of the best layout to be adopted, not to obtain a higher superheat (this point is dealt with in paragraph A), but better behaviour in service, simpler construction, or greater ease in maintenance.

a) Type of superheater you prefer (with elements placed in large or small smoke tubes,...). Reasons for choice;

b) Type adopted for the bends of the superheater elements. (Method of manufacture — minimum distance from the fire box tube plate at which the bend, owing to its method of manufacture can be placed without danger;

c) Method used for connecting the ends of the elements to the superheater header.

Please attach drawings;

d) Do you use dampers, or have you replaced them by some other device ?

In this latter case, please describe the arrangement used and state the results obtained;

What are in addition the instructions issued to the drivers when running with the regulator closed ?

2. — Pyrometers for superheated steam.

a) Type (saturated steam, thermocouple,...) and maker (Fournier, Siemens-Halske,...) of the pyrometers used;

b) Do the instruments give complete satisfaction as regards behaviour in use?

c) Are all the superheated locomotives fitted with pyrometers? Do you think it necessary to equip all your superheated locomotives with pyrometers ?

d) When the locomotives are not fitted with pyrometers has any provision been made so that a pyrometer can be fitted quickly, for trial purposes ?

3. — Lubrication of valves and pistons.

a) α — Superheat cylinder oil *used* [Description, nature and proportion of constitutents, density (if possible at 15° C. = 59° F.) pour point, flash point, viscosity at different temperatures, amongst which 100° C. (212° F.) (with of course mention of the viscometer used), reaction. Attach specifications];

β — Do these oils give complete satisfaction, particularly at high superheats (the value of which should be given) ?

Are you considering any alterations in your specifications and if so what are they?

γ — Have you made tests (laboratory and practical) in order to determine the relationship existing between each of the usual characteristics of the oils and the lubricating value. If so, what results have you obtained ?

b) α — Kind (mechanical, displacement...) and make (Friedmann, Detroit,...) of the lubricators adopted;

β — Reasons for the kind of lubricator chosen being selected;

γ — Non return valves placed on the lubricator supply pipes. (Description with drawings and remarks on the efficiency of the valves);

c) Number of feeds per cylinder and valve (HP and LP);

d) Where do the different lubrication pipes discharge in the steam ?

e) Do you use any lubricant other than oil, either alone, or mixed with oil ? Fittings used with this object in view.

4. — Slide valves.

Alterations made in the construction of the valves since 1922.

5. — Valve spindle and piston rod packings.

a) Types used at the present time, or under trial.

For each type give the following information :

α — Description of the packing with drawings. (State in particular, the compositions of the alloy of the rings, the melting temperature of this alloy, the temperature of the steam in contact with the packing, the class and the composition of the metal of the piston rod.)

β — Position of the packing valve spindle or piston rod, steam or exhaust side);

γ — Lubrication of the packing. How carried out and with what lubricant ?)

δ — Behaviour in service [give in particular the life of the rings (in kilometres) with an indication of the kilometrage run between two liftings];

ε — General remarks.

b) Effect of the temperature of the superheat upon the choice of packing and on the method of lubrication.

c) What type of packing has been made general?

6. — Relief valves. Air admission valves. By-pass.

a) What has been your experience since the Rome Congress as to the need for and the effect of relief valves, snifting valves and by-pass valves ?

b) What is the latest design of relief valves, snifting valve and by-pass valve used ?

Please attach, if not already published in the Bulletin, descriptions and drawings;

c) Do you think there is any value in using snifting valves and by-pass valves together? Is this your practice?

Which of the three following arrangements do you consider the best ?

— snifting valves or
— by-pass valves or
— snifting valves with by-pass valves.

If you prefer the by-pass (either alone, or with snifting valves) what method of working (by hand, automatic, servo-motor with compressed air or steam) do you think the best ?

CHAPTER III.

Feed water heating.

1. — Position as regards feed water heating of your steam locomotive stock.

a) Give the information for *feed water heaters properly speaking* in the form of a table (table II) as per attached copy;

b) Give the information for *exhaust steam injectors* in the form of a table (table III) as per attached copy.

Please conform to the notes.

2. — For each of the types of feed water heater mentioned in tables II and III give the following information :

a) Is the feed water heater easily operated ? How is it known that the pump or injector is feeding normally? How is it known that the water is being properly heated?

Are the instruments or means of control, and in particular the pyrometers (the type of which should be mentioned) entirely satisfactory?

b) α — Average temperature of the feed water on leaving the heater (or each heater if there are several);

β — Between what limits does the temperature of the water vary from the average when working a train ?

c) Results of trials *made by you,* and concerning :

α — the quantity of hot water supplied;

β — the consumption of live steam (in the case of equipment driven by steam from the boiler) or the power required to drive the pump (for pumps driven from the motion);

d) α — Saving of fuel (at equal power.

It is desirable to consider the saving shown by the equipment, first on the fuel used on the run only, then on the total fuel used (including therefore that used when in shed);

β — Increase in power (at equal fuel consumption);

γ — Saving of water;

e) Effect of fitting a feed water heater upon the superheat temperature of the steam.

Give results of any tests that have been made, and the results obtained from them;

f) Effect of fitting the feed water heater on the draft (as the result for example of taking exhaust steam for exhaust steam heaters or through the alteration of the flue tubes in the case of combustion gas heaters).

Indicate the alterations, if any, made to the blast pipe (attach drawings showing the layout before and after fitting the feed water heater).

Also give particulars, if known, of the back pressure at exhaust recorded on engines fitted and not fitted with feed water heaters when working under similar conditions;

g) Effect of the feed water heater on the partial purification of the feed water before its introduction into the boiler and upon the cost of boiler maintenance.

Any definite facts on these points should be given;

h) Type of oil separator used with surface heaters (give a description with drawings).

Remarks on the working of these oil separators. Have you in particular, observed any trouble attributable to the feed water containing traces of oil? What is, in the event of your having measured it, the proportion of oil remaining in the heated water?

i) Any particular observations made on the behaviour of the various parts of the feed water heater in service.

What does the usual running maintenance consist of? Attach the instructions issued to the drivers and the depots.

Have you had any cases of water being carried over into the locomotive cylinders from the condensers? Have any successful measures been taken to avoid water being carried over?

j) Precautions taken to prevent damage through the heaters freezing up. Results obtained;

k) What is the cost of maintenance of the feed water heater both per kilometre and per annum?

l) Over what period is the cost of the equipment paid off (taking into account the first cost and the installation and maintenance costs and the economies obtained...)?

m) Your opinion of the feed water heater in general.

3. — Conclusions.

a) Of the feed water heaters tested which do you consider the most useful? Reasons for the choice made;

b) Are you considering extending the use of feed water heaters?

c) What types of locomotives do you think should be first fitted (on compound locomotives or on simple, on passenger, or on goods locomotives,...)?

4. — Have you tested arrangements for avoiding the use of cold feed water when running with shut regulator (reserve supply of hot water, auxiliary steam supply,...)?

If so, please give the following information:

Description of the arrangement.

Quantity of the reserve supply of hot water provided.

Increase in weight (water included) due to the arrangement.

Number of engines equipped. Leading characteristics of the locomotives fitted.

Advantages resulting from the arrangement.

Maintenance.

Conclusions.

5. — Give here all particulars which do not come under the above headings.

CHAPTER IV.

Air preheating.

Have you tested any arrangements for heating the combustion air ?

If so, please give the following information :

a) General characteristics of the locomotives fitted;

b) Description of the installation (attach drawings);

c) Increase in weight due to fitting the air heater to the locomotive;

d) Number of engines fitted;

e) Results obtained;

f) Maintenance;

g) Conclusions.

CHAPTER V.

Motion.

1. — What *type of motion* are you using generally ?

2. — Give for the most recent types of express passenger and goods engines the *valve events* in the form of a table on the lines of the model of appendix III. In order that the information supplied by the railways may be compared, appendix II shows how the valve events should be given.

3. — Conjugated valve gears and comparison thereof with independent valve gears.

a) *Simple expansion* locomotives;

b) *Compound expansion* locomotives.

For each of the two cases, *a* and *b* above, please give the following information :

α — Description of the arrangement used for conjugating the gears. Attach general arrangement drawings of the motion used on a recent class of locomotive (or, if so fitted, on several classes) with the valve events given by the motion in the form of a table on the lines of that of appendix III.

Give for the compound locomotives the basic ratio between the high pressure and low pressure cut-offs.

β — Comparison between the conjugated and independent gears (as regards construction, repair, easy in handling, free running of the engine, fuel consumption...).

γ — Which of the two (conjugated or independent) do you prefer ?

4. — Have you made any trials with *limited cut off* gear?

If you have, please give the following information :

a) Leading dimensions of the engines in question;

b) Description (with drawings attached) of the arrangement tested;

c) Number of locomotives with limited cut off (per class of locomotive);

d) Results obtained [compared in particular with locomotives with full gear cut off, the dimensions of which are to be given as asked for under *a*];

e) Conclusions.

5. — Have you tried since 1920 *special valve gears* (such as gears with duplex valves, poppet valve gears, etc...) ?

If so, for each type of gear tested, please give the following information :

a) Principle of the gear (indicate in particular the relationship between the different valve events);

b) Description of the valve and of the gear. Please attach drawings;

c) Give for the classes of locomotives the motion drawings of which have been sent in (*b*, above) the valve events as a table in the form of appendix III;

d) Number of engines fitted (per class of locomotive);

e) Results obtained, and comparison between locomotives with the usual type of gear (in particular, effect of the valve gear on the back pressure at exhaust and in the fuel consumption);

f) Is the gear easily to be handled ?

g) Maintenance;

h) Cost of repairs;

i) Conclusions.

6. — Give here all supplementary information not coming under the above headings.

CHAPTER VI.

Drast and Exhaust (1).

1. — What *type of exhaust have you used up to the present ?*

Attach drawings.

Attach also, for the most recent types of express passenger and goods locomotives (the leading dimensions of these locomotives to be given in the form of a table — appendix I), the drawings showing the arrangement of the whole exhaust pipe in the smoke box and giving the dimensions of the smoke box, of the chimney, and of the blast pipe itself.

2. — Have you *tested any new blast pipe arrangements* (Kylälä blast pipe, turbo-exhauster fans,...) ?

If so, please give the following information for each arrangement :

a) Description of the arrangement. Attach designs;

b) Leading dimensions and number per class of the locomotives fitted;

c) Results obtained and comparison with the ordinary locomotive.

Indicate in particular the effect of the arrangement :

α — On the comsumption of fuel;

β — On the exhaust back pressure. [Attach, if available, graphs giving the draft (difference between the vacuum in the smoke box and in the ash pan) in terms of the back pressure.]

γ — On smoke beating down on the boiler;

δ — On throwing fire.

d) Maintenance;

e) Maintenance costs;

f) Conclusions. Do you intend to extend fitting the arrangement ?

3. — Have you tested any *new devices for improving the draft,* independently of the blast (Luftzugumformer, Langer system...) ?

a) Description of the arrangement. Attach designs;

b) Leading dimensions and number per class of locomotives fitted;

c) Results obtained and comparison with the ordinary locomotive.

Indicate in particular the influence of the device :

α — On the fuel consumption;

β — On the exhaust back pressure. [Attach, if available some graphs showing the draft (difference between the vacuum in the smoke box in the ash pan) in terms of the back pressure];

γ — On smoke beating down on the boiler;

(1) The question was studied in detail at the Paris (1900) Congress (see *Bulletin of the International Railway Congress* of 1899, p. 1554; 1900, pp. 563 and 1981; 1901, p. 2509). It was again considered at the Rome 1922 Congress (see *Bulletin* of 1921, pp. 1192 and 1532; 1922, p. 657.

δ — On throwing fire;

d) Maintenance;

e) Repair costs;

f) Conclusions. Do you intend to extend the application of the fitting ?

4. — Do you fit any arrangement to prevent the *smoke from beating down on the boiler in such a way as to interfere with the driver's look-out?*

If so describe the arrangement used (with drawings) and give the results obtained.

CHAPTER VII.

Other improvements in piston locomotives.

A. — *Compounding* (1).

1. — Have you carried out, since 1922, comparative trials between superheated simple and superheated compound locomotives ?

If so describe the tests made and the results obtained with your conclusions.

If not, restate the position you have adopted as regards compounding.

2. — What type (simple or compound have you adopted for the locomotives built since 1922 ?

3. — Have you, since 1922, converted simple locomotives to compound, or vice versa ?

If so, give the leading dimensions of the locomotive concerned.

4. — Value adopted as the ratio of the HP to LP cylinder volumes (in ratio to the boiler pressure).

5. — Statistics as on the 1 January 1922 and the 1 January 1928 of steam locomotives (shunting engines excluded), compound, simple, superheated and saturated.

(1) Question already considered at the Rome 1922 Congress (see *Bulletin of the International Railway Congress Association*, 1923, p. 291.

B. — *Improvements in the combustion.*

1. — Combustion chamber.

a) Leading dimension of the locomotives having boilers with combustion chambers.

Attach drawings, particularly those giving the longitudinal section of the boiler as a whole;

b) Your opinion thereon.

2. — Special grates with forced draft (Hill type grate).

a) Tests carried out and results obtained;

b) Conclusions.

3. Smoke consuming device (1).

a) Summary of results obtained in 1925;

b) Tests made since 1925 and results obtained;

c) Conclusions.

4. — Give here all supplementary particulars relating to *new devices* not falling under any of the above headings.

C. — *Devices to improve the circulation of the water in existing boiler.*

For each device tested (Arch tube, Nicholson Thermic Syphon,...) please give the following particulars :

a) Description of the device. Attach drawings;

b) Leading dimensions and number per type of the locomotives fitted (State metal used for firebox plates);

(1) Question already dealt with at the London 1925 Congress (see the *Bulletin of the Railway Congress* 1924, p. 1029; 1925, pp. 797, 1783 and 2104; 1926, p. 387.

c) Results obtained (in particular, have you found any error in the water level as shown in the gauge glass ? — Comparison of fuel consumption as compared with the ordinary locomotives);

d) Maintenance;

e) Cost of repairs;

f) Conclusions.

D. — *Regulators.*

a) α — Description of *new designs* of regulators tested. Attach drawings.

β — Results obtained (give information, especially as regards the ease of working, the accuracy of control of the admission of steam, steam tightness, wear).

b) Have you tried regulators on the superheated steam side ?

If so, describe the design and give particulars of any supplementary shut off valve that may have been fitted on the saturated side.

What has been the practical result of these designs both as regards the regulator itself, and the effect on the superheater elements ?

E. — *Steam driers on superheated locomotives.*

a) Type and description of the apparatus tested or used. Attach drawings;

b) Tests carried out and results obtained (in particular effect on the superheat temperature);

c) Effect of using steam driers;

α — On the life of superheater elements;

β — Cost of repairs of the locomotive in general;

d) Conclusions.

F. — *Cleaning smoke tubes whilst running.*

a) Type and description of soot blower used;

b) Method of fitting to the boiler (attach drawings);

c) Method of using blower when running;

d) Results obtained (in particular has fitting the blower made it possible to save all tube sweeping on arrival at the depôt ?)

e) Steam used;

f) Maintenance;

g) Conclusions.

G. — *Boosters.*

a) Leading dimensions and number per class of the locomotives fitted with boosters. Indicate for each class to what axle (whether bissel or bogie) the boosters have been fitted;

b) Description of the boosters fitted, with the layout of the pipe work. Comparison between the different types tested. (Attach drawings);

c) Give particulars of recent improvements in the boosters themselves : limited cut off, use of superheated steam...;

d) Results obtained.

State in particular the proportion in which the booster has enabled the speed or alternatively the load of the train to be increased;

e) Effect of fitting a booster on the fuel consumption;

f) Maintenance.

Indicate especially, any particular difficulties experienced in the working and maintenance of the boosters and the steps taken to overcome them;

g) Conclusions and intentions.

H. — *Use of special steels.*

a) Please give particulars of the special steels used in :

α — The valve gear to lighten the moving parts;

β — The frame, and the boiler to lighten the dead weight of the locomotive;

γ — The springs.

Attach the specifications (or other equivalent information). State the heat treatment used;

b) How do these materials behave in service ?

c) Instructions to the sheds as to way parts of special steel are to be dealt with when damaged or worn;

d) In typical cases, such as coupling rods, piston heads and rods, give particulars of the saving in weight effected;

e) What is your standard practice as regards special steels ?

I. — *Use of special light alloys.*

a) Please give information as to the special light alloys such as those of aluminium used for :

α — Moving parts;

β — On the locomotives generally;

Attach the specifications (or other equivalent information);

b) Do you use die castings ? If so, for what purpose ?

c) Saving resulting from the use of these alloys as regards weight, cost of fitting, etc.;

d) Life of parts made from these alloys.

J. — *Lighting of locomotives.*

a) What methods of lighting do you use on your locomotives ?

This refers not only to lighting the cab, but also to all the parts of the locomotive (head and tail lamps in particular);

b) Particulars of the systems used.

When acetyline lighting is used, state especially if one or several generators are used.

In the case of electric light, state in particular, the type, power, voltage, number of revolutions per minute, space occupied, weight, steam used in kgr. per hour by the turbo-generators.

Please give for each system, the candle power of the different lamps;

c) Compare for the different types used :

α — The cost of installing;

β — The running costs (per hour);

γ — The repair costs (per annum);

d) Conclusions. What system of lighting do you consider best and what type are you using generally ?

K. — *Flange lubrication.*

a) Principle and description of the apparatus used or under test. Attach drawings;

b) Method of fitting the apparatus on the locomotives. Attach drawings;

c) Number of locomotives fitted;

b) Behaviour of the flange lubricators in service;

e) α — Lubricant employed;

β — Lubricant consumed (grammes per kilometre and per lubricator);

f) Results obtained (in particular compare the wear of tyres after running 100 000 km. without and with flange lubricators. State the advantages and drawbacks of the various apparatus used or tested...);

g) Can you say to what extent lubricating the flanges reduces the wear of the rails ?

h) Conclusion and intentions of the Company as regards fitting flange lubricators.

L. — *Balancing the moving parts of the locomotives.*

a) What proportion of the weight of the reciprocating parts do you balance? (as a per cent of the total weight of these parts);

b) Do you check the balancing of the coupled wheels by practical test ?

If so, describe the balancing machine and give the method of doing the work.

List of railway administrations who replied to the questionnaire.

SPAIN.

Andalusian.
Catalonian.
Central of Aragon.
Madrid to Caceres, to Portugal and to Western Spain.
Madrid to Saragossa and Alicante.
North of Spain.

FRANCE, ALGERIA AND TUNIS. COLONIES AND PROTECTORATES.

a) France.

I. — *State Railways.*

State Railways.
Alsace & Lorraine Railways.

II. — *Principal Companies.*

Est.
Midi.
Nord.
Paris-Orleans.
Paris, Lyons & Mediterranean.

III. — *Light Railway Companies.*

Chauny to Saint-Gobain.
Tarn Department.

b) Algeria and Tunis.

State Railways, Algerian lines.
Paris, Lyons & Mediterranean Company, Algerian lines.
Tunisian.

c) Colonies and Protectorates.

AFRICA.

French West African Railways.
Dahomey Railway Company.

ASIA MINOR.

Damas-Hamah Railway and extensions.

INDO CHINA.

Indo China and Yunnan Railway Company.

ITALY.

I. — *State Railways.*

State Railways.

II. — *Private Companies.*

Mediterranean Railways.
North of Milan Railway.

APPENDICES III, IV, V, VI and VII

Improvemen

Order No.	Leading dimensions of locomotives: Class of locomotives.	Type of locomotives.	Class of work used on.	Diameter of the coupled wheels, in metres).	Simple expansion or compound.	Number of cylinders.	Grate area, square metres.	Boiler pressure, in kgr. per cm².	Seri of tes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10
									S
1	4301-4310	241	Passenger.	1.750	Compound	2 HP 2 LP	5.00	16	...
									Madrid to Sara
2	1301-1308	240	Fast.	1.600	Compound	2 HP 2 LP	4.10	16	...
									N
3	4601-4606	241	Fast.	1.750	Compound	2 HP 2 LP	5.00	16	...
									Fr
									Al
4 5 6	S-14	231	Fast and express.	1.940	Compound	2 HP 2 LP	4 27	16	lst. class motive originally 2nd. c 3rd. c
									F
7	41001	241	Fast	1.950	Compound	4	4.43	16	...
8	5286 to 5335	150	goods.	1.400	simple expansion	3	3.25	14	...

Column (2). — Usual classification of the Company.
Column (3). — The type of locomotive to be given in the form of a three figure number, the hundreds, tens, and
Column (16). — If the boiler tube is ferruled with inside ferrule, the diameter to give is the inside of the ferrule (the
Column (24). — It applies in this case to the bend nearest the firebox.

Details of the nest of boiler tubes and superheater flues.

	Boiler tubes.					Superheater flues			Superheater.				
th e s n s, s)	Kind of tubes (smooth or ribbed).	Number.	Nominal diameter (in millimetres) inside.	Nominal diameter (in millimetres) outside.	Interior diameter at swaged end at firebox tube plate (in millim.)	Number	Nominal diameter (in millimetres) inside.	Nominal diameter (in millimetres) outside.	Type of superheater.	Nominal diameter of the superheater elements (in millimetres) inside	Nominal diameter of the superheater elements (in millimetres) outside.	Shape of element carriers.	Distance of spear end from firebox tube plate (in metres).
	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
n.													
	plain	132	50	55	...	36	125	133	Schmidt flue tube superheater.	30	38	...	0.200
licante.													
	plain	185	45	50	...	24	130	138	Schmidt flue tube superheater.	30	38	...	0.550
ain.													
	plain	155	50	55	...	30	125	133	Schmidt flue tube superheater.	30	38	...	0.327
ine.													
	plain	151	50	55	50	24	125	133	Schmidt flue tube superheater.	31	38	2.5 mm. plate.	0.550
	do.	151	50	55	50	24	125	133	do.	28	35	id.	0.550
	do.	136	45	50	40	24	130	138	do.	31	38	id.	0.550
	plain	130	50	55	48	30	130	138	DM	31	38	...	0.600
	do.	148	50	55	48	32	130	138	DM	31	38	...	0.450

ting the number of leading carrying axles, the coupled axles, and the trailing carrying axles.
to be written below the figure of the diameter).

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Order No.	Class of locomotives.	Type of locomotives.	Class of work used on.	Diameter of the coupled wheels, (in metres).	Simple expansion or compound.	Number of cylinders.	Grate area, square metres.	Boiler pressure, in kgr. per cm².	Ser of te
	Leading dimensions of locomotives								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(1
									F
									F
9									Ist clas as origi
10									2nd c
11	141000	141	Heavy goods over heavy gradients.	1.650	Simple expansion.	2	3.80	12	3rd c
12									4th c
13									5th c
									F
14	3101-3120	231	Fast and express.	1.940	Simple expansion.	2	4.00	13	...
									F
15	31241-31250	231	Fast.	1.900	Compound.	2 HP 2 LP	3.50	16	..
16	4301-4340	140	Heavy goods and express.	1.550	do.	do.	3.22	16	..
17	5008-5015 5019-5022 5031-5050	150	Heavy goods.	1.550	do.	do.	3.22	16	..
									Paris,
18									Ist clas as origi
19									2nd c
20	140-A 1 to 170	140	Fast goods.	1.650	Simple expansion.	2	3.00	14	3rd c
21									4th c
22									5th c
23									6th c
24									Ist clas as origi
25									2nd c
26	231-D 1 to 230	231	Fast and express over easy gradients.	2.000	Compound.	2 HP 2 LP	4.25	16	3rd c
27									4th c
28									5th c
29									6th c

...ngth of ...oke ...bes ...be-...een ...ube ...ates, (in ...tres).	Details of the nest of boiler tubes and superheater flues. — Boiler tubes.					Superheater flues			Superheater.				
	Kind of tubes (smooth or ribbed).	Number.	Nominal diameter (in millimetres) inside.	Nominal diameter (in millimetres) outside.	Interior diameter at swaged end at firebox tube plate (in millim.)	Number	Nominal diameter (in millimetres) inside.	Nominal diameter (in millimetres) outside.	Type of superheater.	Nominal diameter of the superheater elements (in millimetres) inside.	Nominal diameter of the superheater elements (in millimetres) outside.	Shape of element carriers.	Distance of spear end from firebox tube plate (in metres).
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
...ntinued).													
...te.													
...30	Plain.	151	50	55	50	24	125	133	Schmidt flue tube superheat.	31	38	...	0.450
...30	do.	101	50	55	50	24	125	133	do.	31	38	...	0.450
...30	do.	151	50	55	44 (ferrule).	24	125	133	do.	31	38	...	0.450
...30	do.	151	50	55	44 (ferrule).	24	125	133	do.	31	38	New type carrier.	0.450
...30	do.	151	50	55	44 (ferrule).	24	125	133	do.	28	35	do.	0.450
...di.													
...05	Plain.	123	52	57	45 (ferrule).	28	125	133	Schmidt flue tube superheat.	29	36	...	0.500
...rd.													
...55	Ribbed. Plain.	62 21 31	65 45 50	70 50 55	61 35 46	30	125	133	A	31	38	...	0.470
...55	Plain.	90	65	70	61	24	125	133	A	31	38	...	0.470
...05	Plain.	82	64	70	61	24	125	133	D	31	38	...	0.470
Mediterranean.													
...4	Plain.	120	50	55	48	21	125	133	Schmidt flue tube superheat.	31	38	...	0.450
...4	do.	120	50	55	40 (ferr.)	21	125	133	do.	31	38	...	0.450
...4	do.	120	50	55	48	21	125	133	do.	28	35	New type carrier. (see fig. 2).	0.450
...4	do.	120	50	55	40 (ferr.)	21	125	133	do	28	35	do.	0.450
...4	do.	106	51	55	47	21	135	143	do.	28	35	do.	0.450
...4	do.	106	51	55	40 (ferr.)	21	135	143	do.	28	35	do.	0.450
...3	do.	143	51	55	47	28	125	133	Schmidt flue tube superheat.	28	35	...	0.690
...3	do.	143	51	55	40 (ferr.)	28	125	133	do.	28	35	...	0.690
...3	do.	143	51	55	47	28	125	133	do.	28	35	New type carrier.	0.450
...3	do.	143	51	55	40 (ferr.)	28	125	133	do.	28	35	do.	0.450
...3	do.	128	51	55	47	26	135	143	do.	28	35	do.	0.450
...3	do.	128	51	55	(40 ferr.)	26	135	143	do.	28	35	do.	0.450

Order No.	Leading dimensions of locomotives								Seri of tes
	Class of locomotives.	Type of locomotives.	Class of work used on.	Diameter of the coupled wheels, (in metres).	Simple expansion or compound.	Number of cylinders.	Grate area, square metres.	Boiler pressure, in kgr. per cm².	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10
									F
									Paris, Lyo
30 31 32	241-A 1 to 95	241	Fast and express. Heavy loads over heavy gradients.	1.790	Compound.	2 HP 2 LP	5.00	16	1st class as orig. 2nd cl 3rd cl
									Pari
33	4062 S	230	Stopping (passenger and goods) on the level.	1.800	Compound.	2 HP 2 LP	3.14	16	loco. as inally f
									Itali
34	Group 744	140	Fast.	1.630	Simple expansion	2	3.50	12	..
35	Group 746	141	Heavy fast trains over heavy gradients	1.880	Compound.	2 HP 2 LP	4.30	14	...
									Nor
36	280	230	Fast.	1.620	Simple expansion	2	2.40	12	...
									Medit
37	170	130	Mixed	1.000	Simple expansion	2	1.30	12	...
									Belg
									Belgi
38 39	Type 10	231	Fast over heavy gradients.	1.980	Simple expansion	4	5.00	14	1st class as orig. 2nd cl

Details of the nest of boiler tubes and superheater flues.												
Boiler tubes.					Superheater flues			Superheater.				
Kind of tubes (smooth or ribbed).	Number.	Nominal diameter (in millimetres) inside.	Nominal diameter (in millimetres) outside.	Interior diameter at swaged end at firebox tube plate (in millim.)	Number	Nominal diameter (in millimetres) inside.	Nominal diameter (in millimetres) outside.	Type of superheater.	Nominal diameter of the superheater elements (in millimetres) inside.	Nominal diameter of the superheater elements (in millimetres) outside.	Shape of element carriers.	Distance of spear end from firebox tube plate (in metres).
(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
...inued).												
...Mediterranean (*continued*).												
Plain	145	50	55	46	40	125	133	Schmidt flue tube superh.	31	38	New type carrier.	0.450
do.	145	50	55	40 (ferrule)	40	125	133	do.	28	35	do.	0.450
do.	143	51	55	40	33	135	143	do.	28	35	do.	0.450
...leans.												
Plain	30	40	45	37	25	125	133	Schmidt flue tube superh.	28	35	See fig. 3	0.500
Ribbed	51	65	70	57								
...ate.												
Plain	154	47	52	42	21	125	133	Schmidt flue tube superh.	25	36	...	0.800
do.	180	47	52	42	27	125	133	do.	29	36	...	0.800
...Milan.												
Plain	16	45	50	41	21	125	133	Schmidt flue tube superh.	28	36	...	0.480
Ribbed	63	60	65	54								
...nean.												
Plain	97	41	45	40	12	118	126	Schmidt flue tube superh.	29	35	...	0.295
...tional.												
Plain	230	45	50	...	31	118	127	Schmidt flue tube superh.	27	34	...	...
do.	190	45	50	...	40	125	133	do.	30.5	38	...	...

Order number.	Surface		Sections of gas passages		Resistances to the passage of the gases		Section of steam passage in the elements Q (in square metres).	
	total heating (firebox and tubes) C (in square metres).	Superheat-ing Σ (in square metres).	through smoke tubes in the body of the tubes S_b (in square metres).	through superheater flues in the body of the tubes clear of the supports S_s (in square metres).	of the nest of boiler tubes $R_b \times 10^{-4}$	of the nest of superheater flue tubes $R_s \times 10^{-4}$		$\frac{C}{G}$
(1)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
1	224	99	0.26	0.28	90	30	0.0254	45
								Madrid to Sa
2	201	57	0.29	0.21	96	29	0.0169	49
3	231	84	0.30	0.23	77	36	0.0212	46
								F
4	212	63	0.29	0.18	81	46	0.0181	50
5	212	58	0.29	0.20	81	34	0.0147	50
6	189	63	0.21	0.20	153	32	0.0181	44
7	218	93	0.26	0.28	160	23	0.0226	49
8	203	88	0.29	0.30	119	18	0.0232	63

Note. — The resistance r to the passage of the gases in a tube will be defined by the approximate formula $r = \left(\frac{Cl}{S^3}\right)$ and S the section of the passage of the gases in the tubes.

When calculating r, the metre will be the unit of length taken.

With a view to simplification :

— no account will be taken of swaging or element supports.

— the length of the small tubes will be the length between tube plates.

— as regards the superheater flue tubes, C and S are to be calculated at the place where all the bends of the elements are to

We then get, the letters having the meaning given in this table, D_b being expressed in millimetres and l in metres :

— for a plain tube $r_B = 10^{15} \dfrac{\pi D_B l}{\left(\dfrac{\pi D_B^2}{4}\right)^3}$

— for a flue tube having 4 element bends (Schmidt superheater with flue tubes) $r_s = 10^{15} \times \dfrac{(\pi D_s + 4 \pi d_s) l}{\left[\dfrac{\pi\left(D_s^2 - 4d_s^2\right)}{4}\right]^3}$.

If the nests of boiler tubes and flues are both made up uniformly, we have, $R_B = \dfrac{r_B}{N_B}$, $R_s = \dfrac{r_s}{N_s}$.

cteristic ratios.				Superheat temperature corresponding to average conditions of firing.	Average temperature of the gases of combustion on leaving the nest of smoke tubes		Saving of combustible per 100 tonne-kilometres obtained on one class of locomotive and in relation to the original locomotive as a result of the alterations made thereto.
$\frac{\Sigma}{C}$	$\frac{Q}{G}$	$\frac{R_s}{R_b}$	$\frac{S_s}{S^b}$		in line with the boiler tubes.	in line with the superheater flue tubes.	
(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)
n.							
0.44	0.0051	0 33	1.07	...	...	...	...
Alicante.							
0.28	0.0041	0.30	0.72	...	...	...	..
pain.							
0.36	0.0042	0.46	0.76	...	...	..	...
aine.							
0.29	0.0042	0.57	0.62	280 At the steam chest.	355	225	...
0.27	0.0034	0.42	0.69	300 At the steam chest.	355	250	...
0.33	0.0042	0.21	0.95	360-370 At the steam chest.	300-310	300-310	...
0.42	0.0051	0.14	1.08	...	...	...	...
0.43	0.0071	0.15	1.03	...	...	...	...

represents the total surface of the walls with which the gases are in contact (including, in consequence, the walls of the elements)

Improveme

Order number.	Surface: total heating (firebox and tubes) C (in square metres).	Surface: Superheating Σ (in square metres).	Sections of gas passages: through smoke tubes in the body of the tubes S_b (in square metres).	Sections of gas passages: through superheater flues in the body of the tubes clear of the supports S_s (in square metres).	Resistances to the passage of the gases: of the nest of boiler tubes $R_b \times 10^{-4}$	Resistances to the passage of the gases: of the nest of superheater flue tubes $R_s \times 10^{-4}$	Section of steam passage in the elements Q (in square metres).	$\frac{C}{G}$
(1)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
								I
9	207	64	0.30	0.19	80	45	0.0181	54
10	144	64	0.20	0.19	119	45	0.0181	38
11	207	64	0 30	0.19	80	45	0.0181	54
12	207	64	0 30	0.19	80	45	0.0181	54
13	207	59	0.30	0.20	80	34	0.0148	54
								F
14	202	73	0.26	0.23	84	33	0.0185	51
								F
15	215	57	0.25	0.23	66	29	0.0226	61
16	144	45	0.30	0.19	28	36	0.0181	45
17	252	62	0.27	0.19	45	47	0.0181	78
								Paris,
18	139	44	0.24	0.16	78	41	0.0158	46
19	139	44	0.24	0.16	78	41	0.0158	46
20	139	41	0.24	0.18	78	30	0.0129	46
21	139	41	0.24	0.18	78	30	0.0129	46
22	134	41	0.22	0.22	81	16	0.0129	45
23	134	41	0.22	0.22	81	16	0.0129	45
24	220	71	0.29	0.24	79	30	0.0172	52
25	220	71	0.29	0.24	79	30	0.0172	52
26	220	74	0.29	0.24	79	30	0.0172	52
27	220	74	0.29	0.24	79	30	0.0172	52
28	206	68	0.26	0.27	88	17	0 0160	48
29	206	68	0.26	0.27	88	17	0.0160	48

teristic ratios.				Superheat temperature corresponding to average conditions of firing.	Average temperature of the gases of combustion on leaving the nest of smoke tubes		Saving of combustible per 100 tonne-kilometres obtained on one class of locomotive and in relation to the original locomotive as a result of the alterations made thereto.
$\frac{\Sigma}{C}$	$\frac{Q}{G}$	$\frac{R_s}{R_b}$	$\frac{S_s}{S^b}$		in line with the boiler tubes.	in line with the superheater flue tubes.	
34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)
inued).							
.31	0.0048	0.56	0.63	265 at the steam chest	more than 500	355	...
.44	0.0048	0 38	0.95	300	do. 500	370	— 2.6 %
.31	0.0048	0.56	0.63	285	480	375	+ 13.6 %
.31	0.0048	0.56	0.63	310	440	380	+ 23.9 %
.28	0.0039	0.42	0.67	315	485	425	+ 33.6 %
.36	0.0046	0.39	0.88	...	...	...	...
.26	0.0065	0.23	0.92	...	...	...	...
.31	0.0056	1.28	0.63	...	...	...	...
.24	0.0056	1.04	0.70	...	...	...	...
diterranean.							
32	0.0053	0.52	0.67	225 at the header	...	...	...
.32	0.0053	0.52	0.67	255	...	...	...
.29	0.0043	0.38	0.75	290	...	...	...
.29	0 0043	0.38	0.75	315	...	...	...
.31	0.0043	0.20	1.00	330	...	...	...
.31	0.0043	0.20	1.00	350	...	...	...
32	0 0041	0.38	0.83	260	...	240	...
.32	0.0041	0.38	0.83	295	...	270	...
.33	0.0041	0.38	0.83	300	...	270	...
33	0.0041	0.38	0.83	335	...	280	...
.33	0.0033	0.19	1.04	340	...	290	...
.33	0.0033	0.19	1.04	380	...	310	...

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Order number.	Surface: total heating (firebox and tubes) C (in square metres).	Surface: Superheating Σ (in square metres).	Sections of gas passages: through smoke tubes in the body of the tubes S_b (in square metres).	Sections of gas passages: through superheater flues in the body of the tubes clear of the supports S_s (in square metres).	Resistances to the passage of the gases: of the nest of boiler tubes $R_b \times 10^{-4}$	Resistances to the passage of the gases: of the nest of superheater flue tubes $R_s \times 10^{-4}$	Section of steam passage in the elements Q (in square metres).	$\frac{C}{G}$	$\frac{\Sigma}{G}$
(1)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(3
									Fr
								Paris,	
30	256	114	0.28	0.31	86	28	0.0302	51	
31	256	105	0.28	0.34	86	21	0.0246	51	
32	246	87	0.29	0.35	79	14	0.0203	49	
33	153	43	0.19	0.21	105	23	0.0154	49	
34	192	50	0.27	0.17	107	43	0.0103	55	
35	232	67	0.31	0.22	92	33	0.0178	54	
36	115	32	0.20	0.17	104	27	0.0129	48	
									M
37	67	15	0.13	0.09	177	58	0.0079	52	
									Bel
									B
38	240	62	0.37	0.23	77	33	0.0178	48	
39	...	...	0.30	0.31	93	24	0.0292	...	

otive superheating. APPENDIX III. — B. (*continued*).

eristic ratios.				Superheat temperature corresponding to average conditions of firing.	Average temperature of the gases of combustion on leaving the nest of smoke tubes		Saving of combustible per 100 tonne-kilometres obtained on one class of locomotive and in relation to the original locomotive as a result of the alterations made thereto.
$\frac{\Sigma}{\cdot}$	$\frac{Q}{G}$	$\frac{R_s}{R_b}$	$\frac{S_s}{S^b}$		in line with the boiler tubes.	in line with the superheater flue tubes.	
1)	(35)	(36)	(37)	(38)	(39)	(40)	(41)
nued).							
iterranean *(continued).*							
44	0.0064	0.33	1.11	300 at the header	...	..	...
.41	0.0049	0.24	1.21	320 at the header	...	...	...
.35	0.0041	0.17	1.21	350 at the header	...	..	...
.s.							
28	0.0049	0.22	1.11	345 at the steam chest.	...	...	...
26	0.0029	0.40	0.63	...	...	...	...
29	0.0041	0.36	0.71	...	...	...	...
n.							
28	0.0054	0.38	0.85	...	...	...	...
22	0.0061	0.33	0.69	...	...	...	...
al.							
26	0 0035	0.43	0.62	300 at the steam chest.	...	...	...
.	0.0058	0.26	1.03	345 to 350 at the steam chest.	...	...	...

Characteristics of superheater oils used by c

DESCRIPTION.	Content of			Density		Maximum pouring point.	Inflammability		
	tar (volume) %	asphalt %	ash %	at the temperature of	Value of the specific gravity.		Instrument used to determine it.	Minimum flash point.	Mi pe co
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
									F
No special name	...	0.204	0.013	15° C.	0.900	. .	...	270° C.	3
do.	...	0.8	...	...	0.900 to 0.930	+ 10° C.	...	230° C.	
Galena's superheater oil . .	15	1.5	0.10	30° C.	0.895 to 0.925	+ 15° C.	Luchaire.	275° C.	3
No special name	...	1	0.05	15° C.	0.910 to 0.912	+ 15° C.	...	297° C.	
do.	...	1	0.10	...	0.910 to 0.925	+ 10° C.	Pensky-Martens.	310° C.	
								Paris,	
FVC - 07.	19 to 25	...	0.03 to 0.06	15° C.	0.904 to 0.909	...	...	268° C.	
CN - 30 for locomotives when the superheat is below 300° C.	. .	0.496	0.042	15° C.	0.910	+ 10° C.	Luchaire.	305° C.	3
CN - 31 for locomotives when the superheat is above 300° C.	...	0.858	0.067	15° C.	0.922	+ 10° C.	Luchaire.	321° C.	3

APPENDIX IV.

Administrations given in Appendice II.

	Fluidity (F) or Viscosity (V)						Emulsification factor.	REACTION.
r-	at 35° C.	at 50° C.	at 100° C.	at 150° C.	at 200° C.	at 250° C.		
	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
ine.								
bey. ler.	...	24 27 to 42	176 4	...	...	...	...	...
bey.	...	...	90 to 120	..	700 to 850	...	0 to 5	Neutral.
rbey. gler.	4 to 7	12 to 20 35 to 60	115 to 160 4 to 6	..	...	..	...	Neutral to colored reagents and not attacking metals such as Fe and Cu.
rbey.	...	14 to 20	120 to 135	...	1000 to 1150	...	4 to 5	...
h.								
rbey.	...	...	65 to 80	...	650 to 750	...	...	Neutral to colored reagents and not attacking copper, steel, bronze and antifriction metal.
editerranean.								
rbey.	...	..	146 to 151	...	...	...	3 to 4	...
ans.								
rbey.	.. ...	... ..	97 68	386 332	792 800	1310 1380	... ...	Neutral to colored reagents and not attacking metals such as Fe and Cu.

0

Characteristics of superheater oils used by ce

DESCRIPTION.	Content of			Density		Maximum pouring point.	Inflammability		
	tar (volume) %	asphalt %	ash %	at the tempera-ture of	Value of the specific gravity.		Instru-ment used to deter-mine it.	Minimum flash point.	Mini poi com ti
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(1
Protectorate Coun									
Tur									
No special name	...	1	...	15° C.	0.910 to 0.925	...	Luchaire.	310° C.	.
Damas-H									
do.	10	..	...	15° C.	0.900 to 0.915	...	Luchaire.	300° C.	.
Smyrna-Ca									
« Atlantic 0000 » oil supplied by Messrs. André . . .	...	...	...	15° C.	0.900 to 0.910	...	Luchaire.	350° C.	.
I									
No special name	...	..	...	15° C.	0.900 to 0.950	+ 15° C	Pensky-Martens.	310° C.	
do.	..	...	...	...	...	...	...	305° C.	

APPENDIX IV (*continued*).

Administrations given in Appendix II.

	Fluidity (F) or Viscosity (V)						Emulsification factor.	REACTION.
o- r .	at 35° C.	at 50° C.	at 100° C.	at 150° C.	at 200° C.	at 250° C.		
	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Colonies.								
ays.								
y.	...	...	85 to 125	...	750 to 900	...	...	...
tensions.								
r.	...	90 to 125	...	...	...	...	...	Neutral to colored reagents and not attacking metals such as Fe and Cu.
tension.								
r.	...	50	5 to 7	...	...	...	...	...
r.	...	...	more than 5	...	...	...	...	Neutral.
n.								
.	...	...	5.8	...	...	...	...	...

Types of lubricators used for valve and cylinder lubrication by the Administrations given in Appendix II.

ADMINISTRATIONS.	Type of lubricator.	
	Displacement.	Mechanical.
Spain.		
Andalusian	?	?
Central Aragon	Detroit.	?
Madrid to Saragossa and Alicante	Friedmann.	...
North of Spain	Detroit.	...
France.		
Alsace-Lorraine	? (On old locomotives.)	Michalk. Dicker-Werneburg de Lim
Est	Friedmann.	Manograisseur Bourdon.
	Lavezzari.	...
	Detroit.	...
French State	Michigan.	...
	Detroit.	...
Midi	Detroit.	...
	Friedmann.	...
Nord	...	Telescopompe Bourdon.
Paris, Lyons & Mediterranean	With independent oiler.	Lavezzari.
Paris-Orleans	Detroit.	Telescopompe Bourdon (on test).

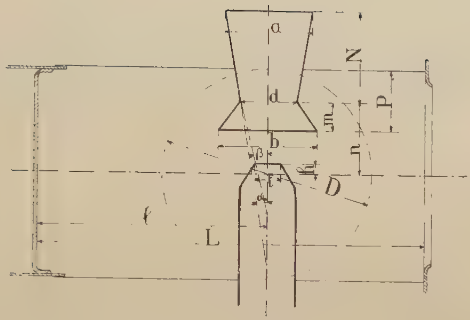
APPENDIX V (*continued*).

Types of lubricators used for valve and cylinder lubrication by the Administrations given in Appendix II.

ADMINISTRATIONS.	Type of lubricator.	
	Displacement.	Mechanical.
Colonies and Protectorates.		
Algerian State Railways	Detroit.	...
Paris, Lyons & Mediterranean (Algerian system).	With independent oiler.	...
Tunisian	Detroit.	...
French West-African	Detroit.	...
Damas-Hamah and extensions	Detroit.	Friedmann.
Smyrna-Cassaba and extension	Detroit. Lavezzari.	... ...
Italy.		
Italian State	...	Michalk.

Particulars of the blast pipe and chimney design in use by the Administratio[n]
given in Appendix II.

ADMINISTRATIONS.	Type of blast pipe.		Particulars from some		
	Fixed.	Variable.	Series.	Types.	a
(1)	(2)	(3)	(4)	(5)	(6)
Andalusian	Circular with petticoat pipe.	Valves. Nord type, mobile cone.			
Central Aragon	Gallez.	...	71-74	240	480
Madrid to Saragossa and Alicante	...	Valves.	1701-1725	241	500
North of Spain	Kylala.	...	4615-4621	241	535
	Circular.	...	4431-4445	140	475
	...	Nord type, mobile cone.			
			France, Colon		
Alsace-Lorraine	Circular.				
	...	P. L. M. clover type.	S-14	231	440
Est	...	Nord type, mobile cone (for compound locomotives) P. L. M. clover type (for simple expansion loco motives).			



ocomotives of the whole : smoke box — blast pipe. — The dimensions are given in millimetres.

d	t	D	l	L	h	m	n	N	P	tg α	tg β
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
00	153	1706	879	1702	— 280	100	670	715	283	0.06	0.13
40	165×150	1940	2041	3000	— 300	185	490	800	665	0.04	...
76	160	1792	1910	3112	— 440	180	650	500	426	...	...
20	140	1900	1025	1700	+ 270	120	770	930	300	0.03	0.28
tectorates.											
25	206	1680	1178	2155	+ 25	235	705	715	370	0.08	0.09

ADMINISTRATIONS.	Type of blast pipe.		Particulars from some cl			
	Fixed.	Variable.	Series.	Types.	*a*	*b*
(1)	(2)	(3)	(4)	(5)	(6)	(7
			FRANCE, Colonies a			
State	...	Nord type, mobile cone. P. L. M. clover type.	141 001-250 ...	141 ...	440 ...	70 ..
Midi	...	Nord type, mobile cone.	3 101-3 120	231	420	72
Nord	...	do.	31 241-31 250	231	480	75
Paris, Lyons & Mediterranean	...	P. L. M. clover type.	241-A	241	479	1 0
Paris-Orleans	...	Nord t pe, mobile cone. P. L. M. clover type.	... 3 50 -3 589	... 231	... 440	.. 78
Algerian State	...	Nord type, mobile cone. P. L. M. clover type.	. . Type 166	... 241	... 445	. 69
Paris, Lyons & Mediterranean (Algerian system)	...	P. L. M. clover type.	...	...	. .	..
Tunisian	...	Nord type, mobile cone.	231 801 to...	231	440	73
Conakry to the Niger	...	Valves.	...	...	...	
Thiès to the Niger	...	Nord type, mobile cone. P. L. M. clover type.	...	...	...	
Damas-Hamah and extensions	Circular.	Nord type, mobile cone.	...	...	...	.
Smyrne-Cassaba and extension.	do.	do.	...	...	...	.
						It
State	Circular.	...	gr. 746	141	510	6

APPENDIX VI (*continued*).

ocomotives of the whole : smoke box — blast pipe. — The dimensions are given in millimetres.

d	t	D	l	L	h	m	n	N	P	tg α	tg β
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
rotectorates (*continued*).											
370	206	1 755	1 303	2 300	— 100	240	650	770	467.5	0 05	0 11
...	...	...	...	...	.	...	...	...	...	...	...
360	210	1 730	1 225	2 045	+ 350	240	840	680	265	0 04	0.15
420	168	1 815	838	1 788	— 40	190	580	830	517.5	0.04	0.20
408	249	1 815	2 212.5	2 972.5	+ 200	398	724	606	581.5	0.06	0.15
...	...	...	...	...	...	...	...	...	...	...	...
325	202	1 680	1 178	2 155	+ 25	235	705	695	370	0 08	0.09
...	...	...	...	...	...	...	...	...	...	...	...
385	212	1 632	1 400	2 230	0	250	650	730	416	0.04	0.13
...	...	...	...	...	...	...	...	...	...	...	...
380	180	1 540	1 090	1 975	+ 70	300	780	870	290	0.03	0.14
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
420	165	1 820	1 293	2 100	— 140	150	495	850	565	0.05	0.20

Statistic

(**Shu**

	Simple expansion.					
	On the 1st January 1922.			On the 1st January 1		
	Satu-rated.	Super-heated.	Total A.	Satu-rated.	Super-heated.	T
Spa						
Andalusian	227	35	262	227	124	
Madrid to Saragossa and Alicante	634	144	778	605	333	
North of Spain	615	310	925	618	419	1
Fra						
Alsace-Lorraine	182	759	941	101	760	
Est	725	635	1 360	393	836	1
French State	1 411	1 270	2 681	1 175	1 270	2
Midi	560	375	935	460	375	
Nord	1 241	680	1 921	1 074	681	1
Paris, Lyons & Mediterranean	1 249	851	2 100	839	1 115	1
Paris-Orleans	547	626	1 173	451	1 051	1
I						
Italian State	2 179	1 498	3 677	1 857	2 119	3

locomotives.

es excluded.

APPENDIX VII.

Compound.					Variation between 1922 and 1928 of the number of :			
he 1st January 1922.		On the 1st January 1928.			Simple expansion locomotives.		Compound locomotives.	
Super-heated.	Total C.	Satu-rated.	Super-heated.	Total D.	(B — A)	$\frac{B-A}{A+C}$	(D — C)	$\frac{D-C}{A+C}$
						Per cent.		Per cent.
...	20	30	5	35	+ 89	+ 31	+ 15	+ 5
39	142	103	39	142	+ 160	+ 17	0	0
42	42	...	93	93	+ 112	+ 11	+ 51	+ 5
114	665	474	148	622	— 80	— 5	— 43	— 2
488	978	160	883	1 043	— 131	— 5	+ 65	+ 3
438	1 237	793	438	1 231	— 236	— 6	— 6	— 0.1
10	315	305	10	315	— 100	— 8	0	0
406	478	72	598	670	— 166	— 7	+ 192	+ 8
581	2 298	1 129	1 949	3 078	— 146	— 3	+ 780	+ 18
184	634	484	227	711	+ 329	+ 18	+ 77	+ 4
55	1 376	1 419	332	1 751	+ 299	+ 6	+ 375	+ 7

[621. 335)

REPORT No. 3

(British Empire, China and Japan

ON THE QUESTION OF ELECTRIC LOCOMOTIVES FOR MAIN LINE TRACTION (SUBJECT VII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Kiichi ASAKURA,

CHIEF OF ROLLING STOCK SECTION, BUREAU OF MECHANICAL ENGINEERING, DEPARTMENT OF RAILWAYS, TOKYO,

and

Hisashi IMAIDZUMI,

MANAGER, ŌI RAILWAY WORKS, TOKYO REGION, DEPARTMENT OF RAILWAYS, TOKYO.

Figs. 1 to 21, pp. 1696 to 1726.

CONTENTS.

1. — Introduction.

Though electric traction, especially electric motor-car service, has for a long time been used advantageously for city and suburban traffic, the electrification of main lines has been undertaken only where special conditions have required or permitted its adoption. Thus electrified main lines are as yet comparatively few, especially in the British Empire, China and Japan.

For this paper, by resolution of the Permanent Commission of the International Railway Congress Association, the writers were assigned to receive data on this subject matter from the countries named, but this data is so meager that as

(1) This question runs as follows: « Electric locomotives for main line traction. — a) passenger locomotives ; b) goods locomotives ; c) locomotives for mountainous country. Multiple unit traction ».

yet there is no reliable foundation on which sufficiently to base a discussion relative to electric locomotives. No type is standard, or in common use, nor is any one type acknowledged to be the best. Therefore, many problems still remain for solution concerning electric locomotives. Some of these problems may be common to all types, but some problems that have developed should be investigated individually in accordance with the system of electrification employed — but such wide investigation is beyond the scope of this report, and, therefore, we shall confine the report mainly to the conditions in Japan, but the data received from the countries assigned to us is tabulated farther on.

In Japan, besides local lines of about 800 km. (500 miles) in length (belonging to fourteen private companies and operated with electric locomotives), we have two electrified sections on the Government Railway System.

One of these sections is on the Tokaidō main line near Tokyo, the most important line in Japan, carrying a dense traffic. The section, about 100 km. (62 miles) in length was electrified a few years ago with a 1 500-volt d. c. system. The other is a steep-gradient section of 1 in 15, about 11 km. (6.8 miles) in length, electrified in 1912 with a 600-volt d. c. system and operated with combined adhesion and rack locomotives. Consequently our experience is at present confined to the operation and problems of d. c. locomotives, chiefly those on the Tokaidō line, but our experiences may be applied to other types of electric locomotives.

2. — General data on electrified railways and their locomotives.

General data on electrified railways and their locomotives are given in tables 1-a to 1-f, which show that the electrified sections are of limited extent, and that the system of electrification is usually of d. c., with different voltages according to the conditions to be met. The locomotives are mostly of the nose-suspension single gear type, the type which prevails in the electrified railways of the countries we were assigned to report on.

3. — Type of drive.

The type of drive for electric locomotives is a big problem. This problem of the most preferable method of power transmission from the traction motor to the driving wheels has, in fact, become the most difficult one to solve since the employment of big electric locomotives for main line traffic. It has often been discussed, but each type of drive has its own merits and demerits, and the problem remains yet unsolved. Some prefer the nose-suspension type, some the collective drive, some the so called individual axle drive, and so on.

In the collective drive, the rods are the source of difficulties. If a powerful electric locomotive is required, especially on direct current operation, two or more traction motors are necessary as has been proved by practice, and if more than two motors are used the construction becomes too complicated.

Considered from this point of view, the individual axle drive type, or nose-suspension type single gear drive, may be more suitably adopted for d. c. locomotives.

In the electrification near Tokyo, the nose-suspension type was adopted for all kinds of service, because of the simplicity and solidity of construction and also for the sake of ample floor space which is especially desired for high tension d. c. Care was taken to minimize the severe

wear of the rail due to this type by reducing the axle load, and also by adding leading trucks as an aid to the traction of the express passenger locomotives on both straight and curved tracks.

As afterwards we purchased two locomotives of the B. B. C. individual axle drive type we made tests to determine the effects of these respective locomotives on the rails and track.

Those used for the test were eight steam locomotives of varied construction, three electric locomotives of the nose-suspension type, two of them being equipped with a leading truck and one without, and an electric locomotive of the individual axle drive type.

The details of the locomotives are given in table 2.

The test was made on the electrified section near Ofuna, where 37-kgr. (74.6 lb. per yard) rails are used. The electric locomotive under test was run with a trailing load consisting of a passenger car and a locomotive, the car being placed between the two locomotives.

The section has straight and curved tracks, the details being as follows :

Radius		Slack		Superelevation	
(metres)	(chains)	(mm.)	(inches)	(mm.)	inches)
600	30	4.5	0 177	30	1.181
400	20	9.0	0.354	60	2.362

From the test, data was obtained necessary to determine the following values :

1. Vertical bending stress of rail.

2. Horizontal bending stress of rail.

3. Vertical deviation (or depression) of rail.

4. Horizontal deviation of rail head.

To determine the bending stress induced in the rails we employed the stremmatographs of Dr. Dudley's system shown in figure 1.

The instrument was fixed, with its two clamps 100 mm. (4 inches) apart, to the bottom of the track rail under question in the middle of said rail between two adjacent sleepers.

As the movements of the recording needle are derived from the movements of one clamp, and as the recording disc is supported firmly on the other clamp, the needle traces on the disc the record of the strain of the rail between the two clamps. The disc is kept revolving at a proper speed during the test. At first on cleared track a base circle is drawn on the disc. Then the locomotive is run at various speeds over the track, and records, corresponding to the strain induced by each wheel of the locomotive, are taken.

Now with the records obtained, we are enabled to find the mean bending stress induced in the rail between the two clamps by assuming the value of E, as the modulous of elasticity. In our case, we valued E = 2 030 000 kgr./cm^2. The maximum bending stress will take place at half way between the two clamps *i. e.*, between the two adjacent sleepers. To get the maximum bending stress, therefore, we must correct the mean stress obtained from the records by multiplying a certain factor, which in our case is found to be 1.05.

As shown in figure 1, the two recording discs are equipped at both ribs of the bottom rail.

In general, the stress in the outer rib (referring to the track center) is larger than that in the inner rib, and a half of the sum of these two stresses in both ribs is called « vertical bending stress », and a half of the difference is called « horizontal bending stress ».

The recorded strain must be read by a special microscope having sufficient accuracy.

General data on electrified rai

NAME OF RAILWAYS.	Japanese Gover		
1. a) Electrified section	Tokyo-Kòzu (77.2		
b) Route mileage	118.8 km.		
c) Track gauge	1 067 mm.		
d) Profile (maximum grade)	1 °/₀.		
2. System of electrification	D. C. 1 500 volts		
1. Locomotive type	AB 10 *	ED 10	ED 1
2. Kind of service	Shunting.	Freight.	Freigl
3. Number of locomotives	2	2	2
4. Wheel arrangement	B	B — B	B —
5. Type of drive	NS & SG +	NS & SG	NS &
6. Number of traction motors	2	4	4
7. One-hour rating of a traction motor :			
a) Terminal voltage (V.)	268	675	675
b) Current (A.)	272	340	400
c) Output (Kw.)	64	210	250
d) Revolutions per minute	480	470	730
e) Ventilation	Self.	Forced.	Force
8. Continuous rating of a traction motor :			
a) Terminal voltage (V.)	268	675	675
b) Current (A.)	...	270	350
c) Output (Kw.)	...	165	220
d) Revolutions per minute	...	510	780
e) Ventilation	Self.	Forced.	Force
9. Gear ratio	4 23	4.47	4 31
10. Diameter of driving wheel (mm.)	970	1 250	1 07
11. Maximum safe speed (km./hr.)	40	65	65
12. Weight of locomotive :			
a) Total (t.)	30.51	56.48	59.6
b) Adhesion (t.)	30.51	56.48	59.6

* This is a battery loco

\+ NS & SG stands fo

their locomotives.

lways.

Kôzu-Atami (25.6 km.).		Ofuna-Yokosuka (16 km.).				
ED 12	ED 13	ED 50	ED 14	ED 15	ED 51	ED 52
Freight.	Freight.	Passenger.	Freight.	Freight.	Passenger.	Passenger.
2	2	17	4	3	3	6
B + B	B + B	B + B	B + B	B — B	B + B	B + B
NS & SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG
4	4	4	4	4	4	4
675	675	675	675	675	675	675
375	350	350	400	340	350	350
225	210	210	250	210	210	210
470	630	630	730	680	630	630
Forced.	Forced.	Forced.	Forced.	Forced.	Forced.	Forced.
675	675	675	675	675	675	675
296	250	250	350	280	250	250
175	150	150	220	178	150	150
510	730	730	780	650	730	730
Forced.	Forced.	Forced.	Forced.	Forced.	Forced.	Forced.
3.91	4.05	3 00	4.31	4.05	2.56	2.56
1 400	1 250	1 250	1 250	1 250	1 250	1 250
65	65	75	65	65	85	85
59.22	64.23	58.32	59.97	58.70	56.60	57.97
59.22	64.23	58.32	59.97	58.70	56.60	57.97

special service.
pension and single gear drive.

General data on electrified rail

NAME OF RAILWAYS.	Ja		
1. a) Electrified section	Tokyo-Kôzu (77.2 km.). Kôzu-		
b) Route mileage	118.8 km.		
c) Track gauge	1 067 mm.		
d) Profile (maximum grade)	1 °/₀.		
2. System of electrification	D. C. 1500 volts.		
1. Locomotive type	ED 53	ED 54	EF 5
2. Kind of service	Passenger.	Passenger.	Passeng
3. Number of locomotives	6	2	8
4. Wheel arrangement	1B+B1	1D1	2C+C
5. Type of drive	NS & SG +	B.B.C. drive.	NS & S
6. Number of traction motors	4	4	6
7. One-hour rating of a traction motor :			
a) Terminal voltage (V.)	675	675	675
b) Current (A.)	340	615	350
c) Output (Kw.)	210	385	210
d) Revolutions per minute	620	700	630
e) Ventilation	Forced.	Forced.	Forced
8. Continuous rating of a traction motor :			
a) Terminal voltage (V.)	675	675	675
b) Current (A.)	270	528	250
c) Output (Kw.)	165	335	150
d) Revolutions per minute	730	750	730
e) Ventilation	Forced.	Forced.	Forced
9. Gear ratio	2.72	3.35	2.56
10. Diameter of driving wheel (mm.)	1 250	1 600	1 400
11. Maximum safe speed (km./hr.)	95	95	95
12. Weight of locomotive : a) Total (t.)	68.32	78.05	97
b) Adhesion (t.)	52.04	59.75	72

+ NS & SG stands for

;heir locomotives (*continued*).

·nment Railways.

km.). Ofuna-Yokosuka (16 km.).				Yokokawa-Karuizawa. 11.1 km. 1 067 mm. 6.66 °/o. D. C. 600 volts (3rd rail).		
EF 51	EF 52	ED 56	ED 57	EC 40	ED 40	ED 41
assenger.	Passenger.	Passenger.	Passenger.	Mountain service.	Mountain service.	Mountain service.
2	7	1	2	12	14	2
1C+C1	2C+C2	B+B	B+B	C	D	B—B
S & SG	NS & SG	NS & SG	NS & SG	Rod drive with rack.	Rod drive with rack.	Rod drive with rack.
6	6	4	4	2	2	3
675	675	1 350	675	540	540	540
340	370	185	380	450	490	367
210	230	230	235	215	240	180
620	786	660	710	550	570	330
Forced.	Forced.	Forced.	Forced.	Self.	Forced.	Forced.
675	675	1 350	675	540	...	540
270	270	155	300	360	...	290
165	165	192	185	175	...	145
730	760	710	750	590	...	360
Forced.	Forced.	Forced.	Forced.	Self.	Forced.	Forced.
2.72	3.38	3.38	4.09	Adhesion 6.5 Rack 5.86	Adhesion 6.46 Rack 5.82	Adhesion 4.95 Rack 3.7
1 250	1 250	1 250	1 400	910	910	1 070
95	95	85	85	27	27	25
84.3	108	61.44	60.9	46	60.70	59.85
69.85	79.2	61.44	60.9	46	60.70	59.85

nsion and single gear drive.

General data on electrified railway
(Ja

NAME OF RAILWAYS.	Hanamakionsen Railway Co.	Ise Railway Co.	Akiho Railway
1. a) Electrified section	Nishimaki-Hanamaki.	Yokkaichi-Tsu-Wakamatsu-Kobe	...
b) Route mileage (km.)	8.4	31.5 — 3.9	16 4
c) Track gauge (mm.)	762	1 067	1 067
d) Profile (maximum grade) (%)	...	...	...
2. System of electrification	D. C. 550	D. C. 1 500	D. C. 6
1. Locomotive type	1	...	...
2. Kind of service	Passenger & freight.	Freight.	Freigh
3. Number of locomotives	1	2	2
4. Wheel arrangement	B	B — B	B
5. Type of drive	NS & SG +	NS & SG	NS & S
6. Number of traction motors	2	4	2
7. One-hour rating of a traction motor :			
a) Terminal voltage (V.)	500	750	500
b) Current (A.)	58	92	44.8
c) Output (Kw.)	22 4	59.7	22.4
d) Revolutions per minute	650	700	600
e) Ventilation	Natural.	Self.	Self.
8. Continuous rating of a traction motor :			
a) Terminal voltage (V.)	500	750	600
b) Current (A.)	25	75	...
c) Output (Kw.)	9.3	48 5	...
d) Revolutions per minute	1 000	700	...
e) Ventilation	Natural.	Self.	...
9. Gear ratio	4.93	4.17	5
10. Diameter of driving wheel (mm.)	864	865	762
11. Maximum safe speed (km./hr.)	19.3	56.4	16.1
12. Weight of locomotive :			
a) Total (t.)	6 6	26	10
b) Adhesion (t.)	6.6	26	10

+ NS & SG stands for

locomotives (*continued*).

Nanbu -way Co.	Ōme Railway Co.	Ryōbi Railway Co.	Fuji-Minobu Railway Co.		Kusatsu Railway Co.	Toyama Railway Co.
awasaki-gimaru.	Tachikawa-Futamatao.	Fukuyama-Fuchū.	Fuji-Kōfu.		...	Minamitoyama-Chigaki.
25 4	23.6	22	88		...	19.5
1 067	1 067	762	1 067		...	1 067
...	...	...	...		...	...
C. 1 500	D. C. 1 200	D. C. 600	D. C. 1 500		..	D. C. 600
...	...	...	200	210	...	...
eight.	Freight & shunting.	Passenger & freight.	Freight.	Freight.	Passenger & freight.	Passenger & freight.
1	1	6	5	3	9	1
— B	B + B	B — B	B + B	B — B	B	...
& SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG
4	4	4	4	4	2	4
575	750	500	675	675	500	600
300	195	80	310	310	...	...
180	101.5	34	186.5	186.5	...	48.5
730	884	705	620	620	...	670
rced.	Self.	Self.	Forced.	Forced.	Natural.	Natural.
575	750	...	675	675	500	..
40	140	...	248	248	...	...
48	73	...	149	149	26.1	...
00	984	...	900	900	...	...
rced.	Self.	...	Forced.	Forced.	Natural.	...
23	5 4	3.88	5.17	5 41	4.53	4.56
250	965	790	1 250	1 250	762	840
5	48.3	45	50	50	...	40 2
.8	40.6	12.2	56	56	10	20
.8	40.6	12.2	56	56	10	20

n and single gear drive.

General data on electrified rai
(J

NAME OF RAILWAYS.	*Ina Railway Co.*		*Musashino Railwa*	
1. *a*) Electrified section.	Tatsuno-Tenryû		Ikebukuro-Han	
b) Route mileage. (km.)	79.7		43.8	
c) Track gauge (mm.)	1 067		1 067	
d) Profile (maximum grade) (°/o)	...		...	
2. System of electrification	D. C. 1 200		D. C. 1 200	
1. Locomotive type	...	..	10	
2. Kind of service	Freight.	Freight.	Freight.	Fre
3. Number of locomotives	6	1	3	
4. Wheel arrangement	B—B	B—B	B—B	B
5. Type of drive	NS & SG +	NS & SG	NS & SG	NS
6. Number of traction motors	4	4	4	
7. One hour rating of a traction motor :				
a) Terminal voltage (V.)	600	600	600	
b) Current (A.)	152	175	142	
c) Output. (Kw.)	78.4	89.6	74 6	
d) Revolutions per minute	680	575	576	
e) Ventilation	Self.	Self.	Forced.	S
8. Continuous rating of a traction motor :				
a) Terminal voltage (V.)	600	600	600	
b) Current (A.)	85	110	110	
c) Output (Kw.)	41	56.7	...	
d) Revolutions per minute.	850	660	760	
e) Ventilation	Self.	Self.	Forced.	
9. Gear ratio.	3.42	3.19	4.06	3
10. Diameter of driving wheel (mm.)	915	915	915	
11. Maximum safe speed (km./hr.)	34.2	31	...	
12. Weight of locomotive : a) Total (t.)	40.6	38.6	33.5	4
b) Adhesion (t.)	40.6	38.6	33.5	4

+ NS & SG stands for nose-sus

heir locomotives (*continued*).

Nankai Railway Co.						
...						
125						
1 067						
...						
D. C. 600						
o. 1	No. 2	No. 3	No. 5	No. 4	No. 6	No. 6
eight.	Freight.	Freight.	Freight.	Freight.	Freight.	Freight.
13	1	1	4	1	1	1
—B	B—B	B—B	B—B	B—B	B—B	B—B
& SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG
4	4	4	4	4	4	4
500	600	500	600	600	600	600
170	152	174	152	102	102	102
73	78.4	74.6	78.4	52.2	52.2	52.2
717	650	795	670	557	551	551
elf.	Self.	Self.	Self.	Self.	Self.	Self.
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
. .	...	...	...	...	...	. .
...	...	...	...	...	...	...
.19	3	3.7	3.42	3.83	3.83	3.83
915	915	915	915	838	838	838
6.4	56.4	56.4	56.4	48.3	48.3	48.3
30	33	30	35	20	22	25
30	33	30	35	20	22	25

gle gear drive.

General data on electrified ra

(.

NAME OF RAILWAYS.	*South-Manc*		
1. a) Electrified section			
b) Route mileage (km.)			
c) Track gauge (mm.)			
d) Profile (maximum grade) (%)			
2. System of electrification			
1. Locomotive type	A.E.G. 22.	Fushun 22	G. E
2. Kind of service	Freight & shunting.	Freight & shunting.	Freig shun
3. Number of locomotives	5	4	3
4. Wheel arrangement	B	B	B–
5. Type of drive	NS & SG +	NS & SG	NS &
6. Number of traction motors	2	2	4
7. One-hour rating of a traction motor :			
a) Terminal voltage (V.)	1 200	1 200	6
b) Current (A.)	42	42	1
c) Output (Kw.)	41	41	7
d) Revolutions per minute	—	—	
e) Ventilation	Natural.	Natural.	Natu
8. Continuous rating of a traction motor :			
a) Terminal voltage (V.)	—	—	—
b) Current (A.)	—	—	—
c) Output (Kw.)	—	—	—
d) Revolutions per minute	—	—	—
e) Ventilation	Natural.	Natural.	Natu
9. Gear ratio	5.62/2.39	5.28/2.48	3.
10. Diameter of driving wheel (mm.)	852	833	9
11. Maximum safe speed (km./hr.)	—	—	
12. Weight of locomotive :			
a) Total (t.)	22	22	
b) Adhesion (t.)	22	22	

+ NS & SG stands for nose-suspension and single gea

eir locomotives (*continued*).

way Co.						*Joshin Railways Co.*
	...					Tokasaki-Shimonida.
	227					35
	1 435					1 067
	..					...
200	D.C. 1 500					D C. 1 500
. G. 50	Fushun 50	G. E. 50	Kawasaki 73	Shibaura 73	Mitsubishi 70	—
ight & ıting.	Freight & shunting.	Freight & shunting.	Freight & shunting.	Freight & shunting.	Freight & shunting.	Freight.
3	4	10	3	2	2	3
—B	B—B	B—B	B—B	B—B	B+B	B—B
& SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG
4	4	4	4	4	4	4
600	600	600	540	600	675	750
176	180	161	420	405	325	78
3.4	93.4	82.2	205	216	194	—
—	—	—	—	—	—	640
ural.	Natural.	Forced.	Forced.	Forced.	Forced.	Self.
	—	—	—	—	675	750
	—	—	—	—	255	76
	—	—	—	—	207	50
	—	—	—	—	490	660
tural.	Natural.	Forced.	Forced.	Forced.	Forced.	Self.
.53	5.53	4.06	5.23	5.44	4.68	4.813
000	1 016	915	1 250	1 100	1 245	900
—	—	50	—	—	50	—
50	50	50	73	73	70	34.5
50	50	50	73	73	70	34.5

General data on electrified ra

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NAME OF RAILWAYS.	*Victorian Railways.*	*South African Railways.*	*London* … .Shil to Nev
1. *a*) Electrified section	...	Masonmill-Glencoe	
b) Route mileage (km.)	270	280	
c) Track gauge (mm.)	1 600	1 067	
d) Profile (maximum grade) (%)	2.5	2.5	
2. System of electrification	D. C. 1 500 V.	D. C. 3 000 V.	
1. Locomotive type	...	...	
2. Kind of service	Freight.	Freight.	Fre
3. Number of locomotives	2 10	95	1
4. Wheel arrangement	B—B	B—B	B+
5. Type of drive	NS & SG +	NS & SG	NS & tw
6. Number of traction motors	4	4	
7. One-hour rating of a traction motor :			
a) Terminal voltage (V.)	725	1 350	75
b) Current (A.)	180	185	31
c) Output (Kw.)	112	224	20
d) Revolutions per minute	585	640	78
e) Ventilation	Forced.	Forced.	Forc
8. Continuous rating of a traction motor :			
a) Terminal voltage (V.)	725	1 350	75
b) Current (A.)	100	155	20
c) Output (Kw.)	64.2	188	13
d) Revolutions per minute	810	705	72
e) Ventilation	Natural.	Forced.	Forc
9. Gear ratio	4.38	4.41	4.
10. Diameter of driving wheel (mm.)	1 065	1 220	1 22
11. Maximum safe speed (km./hr.)	72.4	72.4	72.
12. Weight of locomotive : *a*) Total (t.)	50.7 55 8	68.5	75.
b) Adhesion (t.)	50.7 55.8	68.5	75.

+ NS & SG stands for nose-sus

their locomotives (*continued*).
ire).

rn Railway. Newcastle.	*Metropolitan Railway (London).*	*Underground Electric Railways Co. of London (Metropolitan District).*	*Canadian National Railways.* St. Clair tunnel.		*Canadian National Railways.* Mt. Royal tunnel.
...	...	...	...		.
...	*209	94.5	25		...
...	1 435	...	1 435		...
...	...	2.44	...		...
...	D. C. 600 V.	D. C. 600 V.	A. C. single phase 3 330 V.		D. C. 2 400 V.
...	...	...	...		...
hunting.	Passenger.	Passenger & shunting	Passenger, freight & shunting.		Passenger.
2	20	7	7	2	6
B—B	B+B	B—B	C	D	D
S & SG	NS & SG	NS & SG	NS & SG	NS & SG	NS & SG
4	4	4	3	4	4
600	600	600	290	290	239
94	420	282	1 160	900	...
119	224	150	179	131	...
367	600	625	850	725	...
Natural.	Self.	Self.	Forced.	...	...
600	600	600	290	...	...
94	250	190	...	...	...
119	...	101.5	...	...	...
367	625	780	...	...	...
Natural.	Self.	Self.	Forced.	...	...
3.28	2.48	3.02	5.31	4.33	3.2
915	1 105	915	1 575	1 270	1 168
40.2	104.5	80.5	48.3	...	80.5
56.9	58.3	38.6	64	64.8	84.2
56.9	58.3	38 6	64	64.8	84.2

gle gear drive.

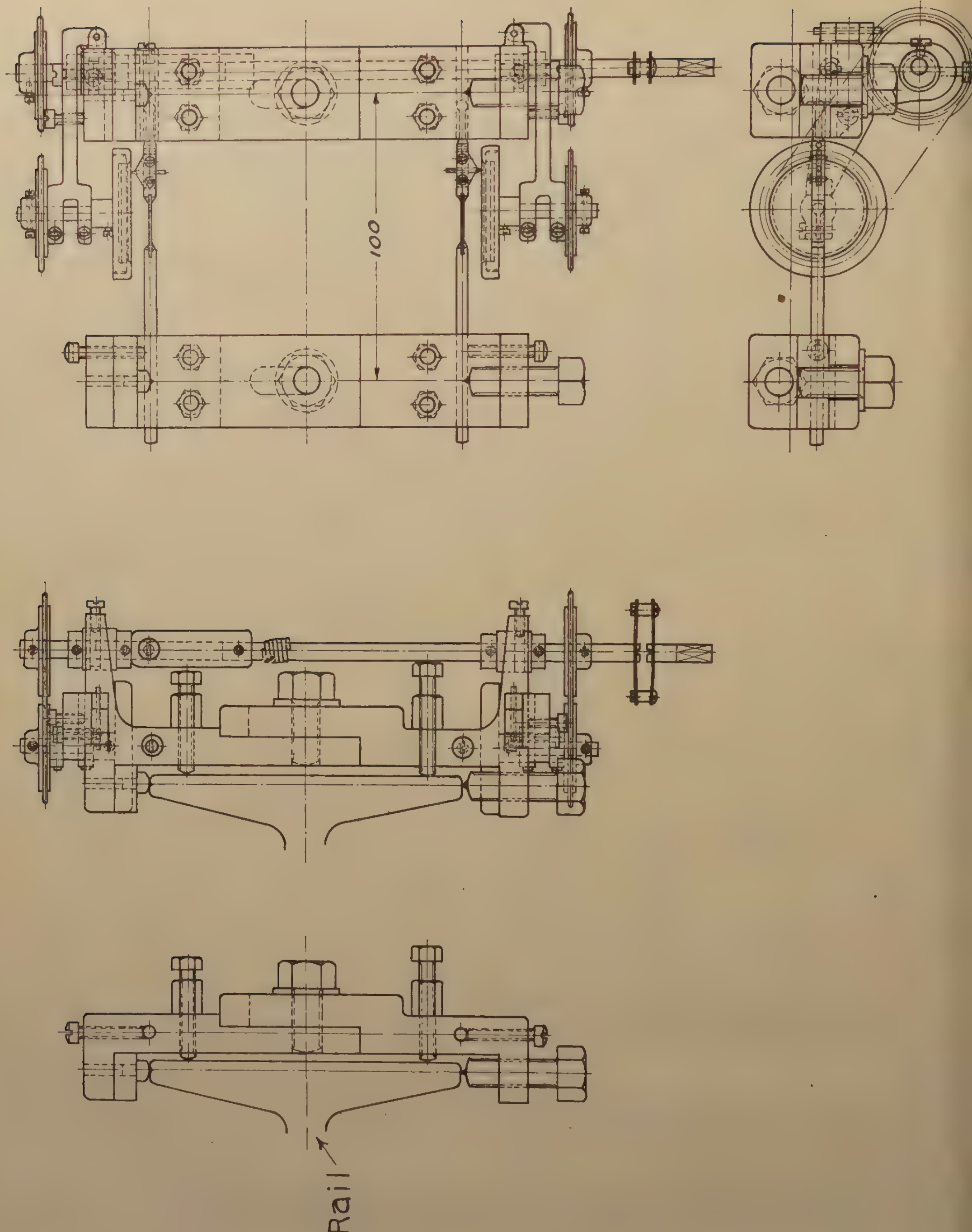

100
Rail

TABLE 2.

Locomotives tested

KIND OF LOCOMOTIVES.	Particulars of locomotives.							
	Type of locomotive.	Wheel arrangement	Total weight in running order.		Total wheel base (millimetres).	Rigid wheel base (millimetres).	Height of center of gravity above rail (millimetres).	Weight on driving axle (tons).
			Locomotive (tons).	Tender (tons).				
Steam locomotive :								
th tender	D 50	1D1	78.14	49.45	9 600	4 710	1 550	14.70
—	9 600	1D	60.35	34.50	7 011	4 572	1 524	13.18
—	C 51	2C1	66.30	44.20	10 000	3 800	1 562	14.06
-	C 52	2C1	82.47	49.45	9 931	3 682	1 605	15.90
—	8 850	2C	55.49	29.45	7 925	3 658	1 524	13.15
—	8 620	1C	46.75	34.50	7 010	4 191	1 553	13.25
—	6 760	2B	45.57	30.52	7 112	2 693	...	13.89
k.	4 100	E	62.06	...	5 792	5 792	1 473	12.41
n.	...	...	62 14	...	8 048	4 137	1 542	13.82
Electric locomotive :								
With leading trucks . .	ED 53	1B+B1	68.32	...	10 060	2 030	...	13.00
	EF 50	2C+C2	97.00	...	18 365	4 267	...	12.00
Mean	...	...	82.66	...	14 213	3 149	...	12.50
Without leading trucks (mean)	ED 51	B+B	57.97	...	8 610	2 820	. .	14.50
B. C. individual axle drive (mean)	ED 54	1D1	78.05	...	9 900	1 900	...	14.94

The deviation of rail is measured by a deflectionmeter invented by Dr. Tanabe (Professor, Kyoto Imperial University), as shown in figure 2.

With the use of this instrument, the depression of the rail and the horizontal deviation of the rail head are recorded simultaneously on a rotating drum, being magnified five times for the former, ten times for the latter. These values are also measured midway between two adjacent sleepers.

Near the middle of a single rail and between two adjacent sleepers, a stremmatograph and a deflectionmeter were attached — and this was done on three lengths of adjoining rails on each side of the track, thus enabling six stremmatograph and six deflectionmeter records to be obtained on a single test run. The

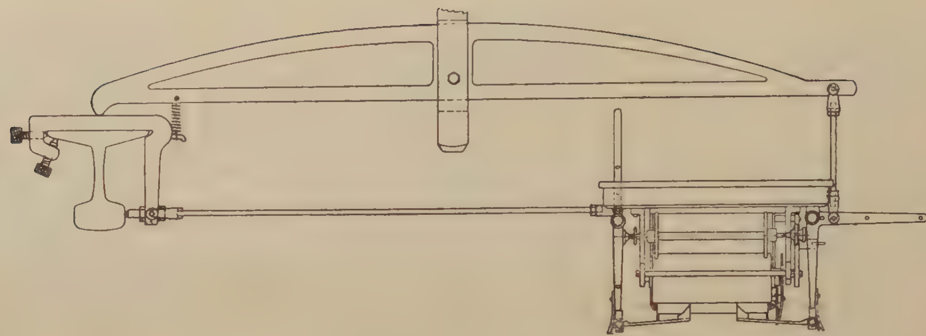


Fig. 2. — Deflectionmeter.

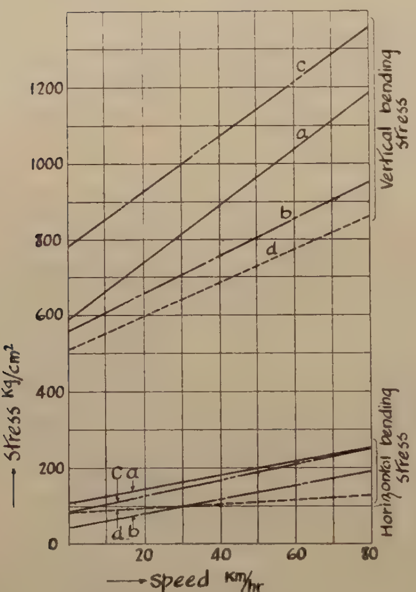


Fig. 3. — Mean value of maximum stresses in rail induced by driving wheels (straight track).

——— *a* Steam locomotive.
—·—·— *b* Electric locomotive (nose suspension with leading truck).
—··—·· *c* Electric locomotive (nose suspension without leading truck).
------- *d* Electric locomotive (B. B. C., individual axle drive).

test was made 30 times for the respective speeds of each locomotive.

Test results were plotted — taking the stresses induced by driving wheels in ordinates and the speeds in abscissa. As is generally the case, the results plotted vary considerably in range, but we could determine from the plottings that the relation between the stresses and the speed is properly assumed to be straight lines, each line corresponding to each locomotive. Mean positions for the straight lines were determined for steam locomotives, for nose-suspension type electric locomotives with leading trucks and without leading trucks, and for individual axle drive type electric locomotives.

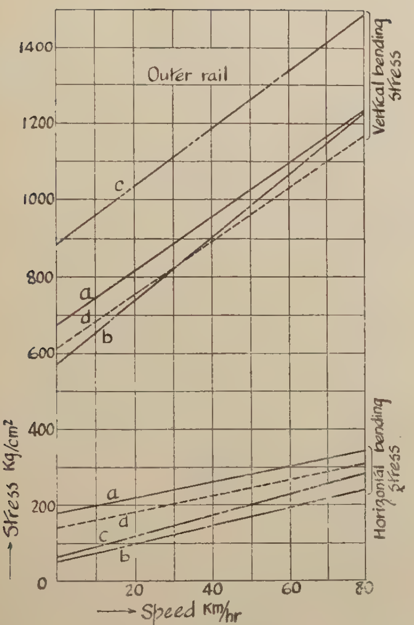
These straight lines are shown in figures 3, 4, and 5.

Figure 3 shows the result on the straight track; figure 4 that on the curved track of 600-metre (30 chains) radius, and figure 5 that on the track of 400-m. (20 chains) radius.

The relation between the deviations and speeds are likewise shown by straight lines, as given in figures 6, 7, and 8. The values of stresses and deviations for the speed of 60 km. per hour are given in tables 3, 4, and 5.

From the tables and diagrams given above, we find the following :

1. On straight track (figs. 3 and 6).



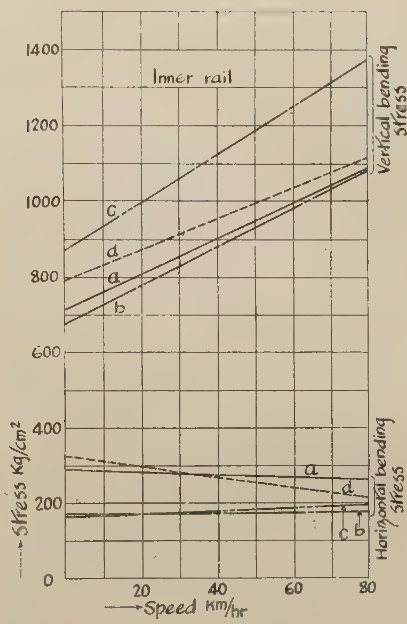
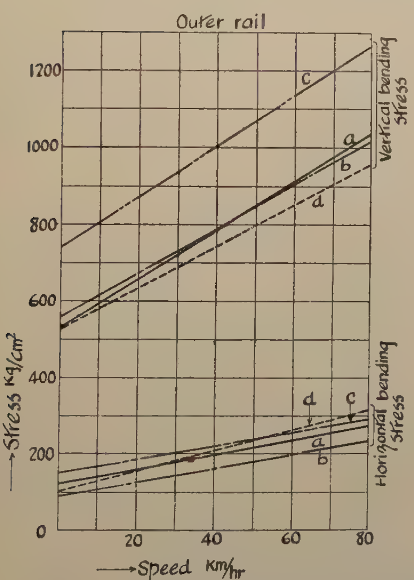


Fig. 4. — Mean value of maximun stresses in rail induced by driving wheels [(curved track, radius = 600 m. (30 chains)].



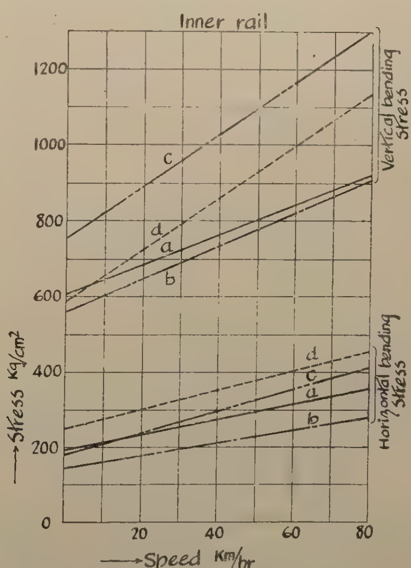


Fig. 5. — Mean value of maximum stresses in rail induced by driving wheels [curved track, radius = 400 m. (20 chains)].

So far as the vertical bending stress is concerned, the electric locomotive of nose-suspension type without leading trucks shows much higher stress than that of the steam locomotive, while the nose-suspension type with leading trucks compared with the steam locomotive shows less stress. B. B. C. individual axle drive type shows the least stress both for vertical and horizontal bending stresses.

For the deviation of rail, the steam locomotive gives the highest values, the nose-suspension type with leading trucks, the lowest.

2. On curved track (R = 600 m. [30 chains]) (figs. 4 and 7).

The vertical stress induced by the electric locomotive of nose-suspension type without leading trucks is much more pronounced when compared with the other type both for the outer and the inner rails.

The stress due to the electric locomotive of nose-suspension type with leading trucks shows good results in all cases, while that of B. B. C. individual axle drive appears to have no particular merit.

As to the deviation of the rail, there is not much difference in the locomotives, except in the horizontal deviation of the rail head of the outer rail, in which the steam locomotive gives the highest value, the nose-suspension type without leading trucks, the lowest.

3. On curved track (R = 400 m. [20 chains]) (figs. 5 and 8).

The electric locomotive of nose-suspension type without leading trucks gives the highest vertical bending stress, and the B. B. C. drive type also shows high values, especially on the inner rail.

The electric locomotive of nose-suspension type with leading trucks shows the least stress in all cases, except that of the vertical bending stress in the outer rail.

For the deviation of rail, there is not much difference in the locomotives, except in the vertical deviation of the outer rail, in which the nose-suspension type without leading trucks gives comparatively higher values than the others.

It is, however, rather difficult from these test results to say positively which is the best type of the locomotives tested.

Of course, we cannot exactly judge the direct effect of the respective locomotives upon the track from the stress and deviation given above, but we can imagine with reasonable safety that the locomotive which shows the smaller values of stress and deviation would be the best both for maintaining the locomotive itself and for the track.

Thus it may be reasonably assumed that, based on the above premises, the effect of the locomotive upon the track, as shown by the diagrams, is correct.

So far as our actual electric operation has gone, it has been proved that the expense in connection with the maintenance of track is greater now than it was, when only steam operation was employed. Some of our engineers have estimated the increased amount of expense at about 20 %, roughly, though we have no statistical data available.

But this increase in expense cannot be declared simply as the result of the change in prime movers, because the effect of the electric locomotive on the track seems to be quite different from that of the steam locomotive.

Necessarily we now have to note, especially in the transition stage from steam operation to electric operation, that the unfavorable effect of electric locomotives upon track attacks the weak points of track used for steam operation, and therefore, that the method of maintenance of track should be changed accordingly.

In the case of electric operation, much more attention should be given toward

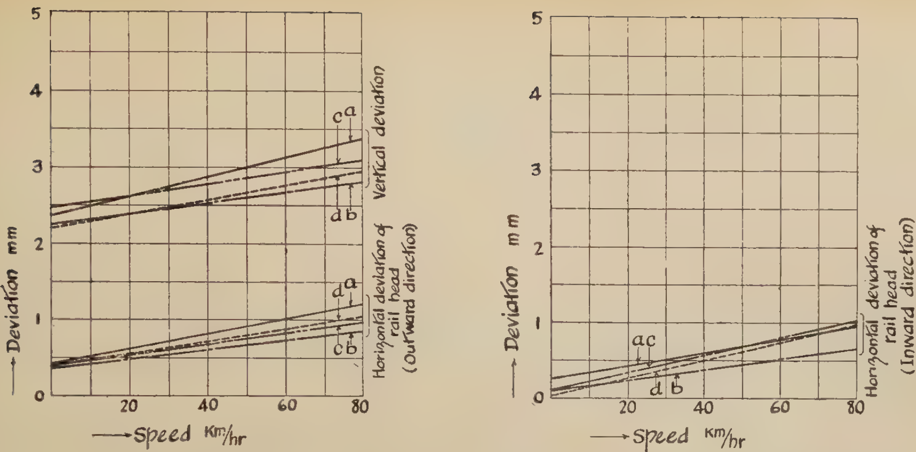


Fig. 6. — Mean value of maximum deviations of rail induced by driving wheels (straight track).

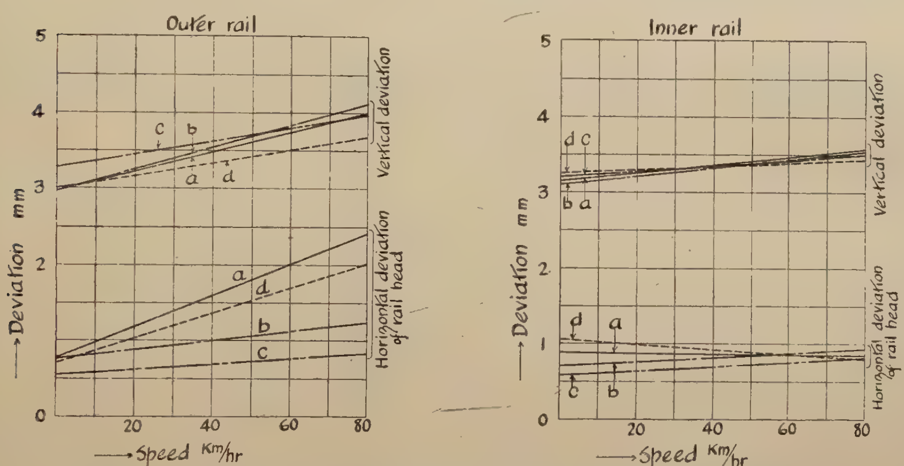


Fig. 7. — Mean value of maximum deviations of rail induced by driving wheels [(curved track, radius = 600 m. (30 chains)].

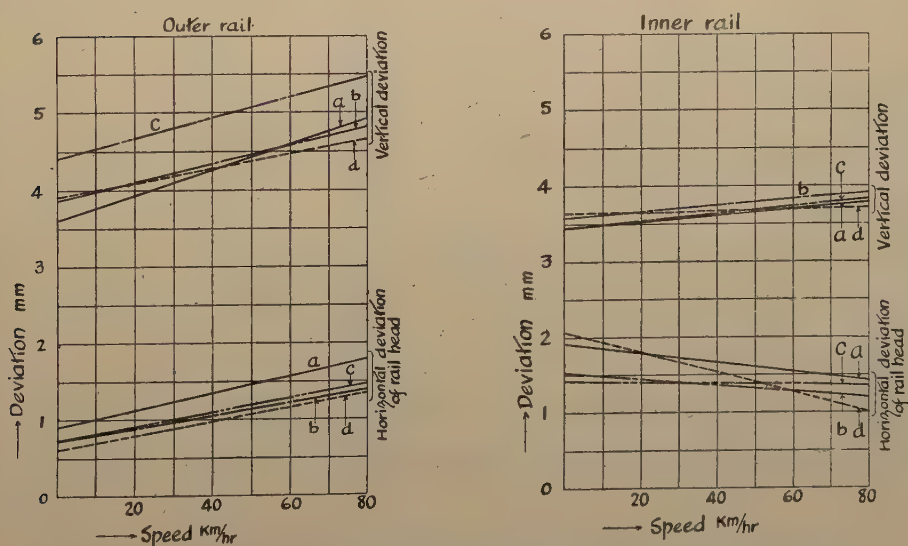


Fig. 8. — Mean value of maximum deviations of rail induced by driving wheels [(curved track, radius = 400 m. (20 chains)].

Mean values of maxi

induced by driving wheels of each locomotive at the speed of 60 km. per

KIND OF LOCOMOTIVES.		Type of locomotive.	Vertical bending stress.		STRA b
			Stress (kgr./cm²).	Increase (%)	Stress (kgr./cm
Steam locomotive :					
With tender		D 50	932	72	214
Do.		9 600	901	82	160
Do.		C 51	987	70	205
Do.		C 52	1 186	84	228
Do.		8 850	1 051	79	193
Do.		8 620	1 003	61	182
Do.		6 760	1 392	90	369
Tank		4 100	867	78	161
Mean		..	1 040	77	214
Electric locomotive :					
Nose-suspension.	With leading trucks	E D 53	887	56	162
		E F 50	817	49	143
	Mean	...	852	53	153
	Without leading trucks (mean)	E D 51	1 215	56	210
B. B. C. individual axle drive (mean)		E D 54	775	53	122

Remark : As the centre peg of the deflectionmeter moves slightly due to vibration of earth, the test results abou

sses and deviations

their per cent increase as compared with those of the locomotive at rest.

;K.						
	Vertical deviation of rails.		Horizontal deviation of rail head.			
			Outward direction.		Inward direction.	
Increase (°/o).	Deviation (millimetres).	Increase (°/o).	Deviation (millimetres).	Increase (°/o).	Deviation (millimetres).	Increase (°/o).
57	3.52	32	0.81	113	0.57	233
57	3.33	26	0.76	100	0.67	235
107	3 08	28	0.96	159	0.73	317
74	3.22	33	1.25	131	1.11	162
245	2.90	37	0.82	122	0.73	152
41	2 92	29	1 05	102	0.69	277
162	3.20	42	1 14	115	0.75	168
58	3.02	35	1.41	236	1.01	359
100	3.15	33	1.03	135	0.78	218
146	2.78	22	0.76	73	0 62	313
361	2.63	19	0.75	109	0.42	500
254	2.71	21	0.76	91	0.52	407
133	2.97	20	0.87	102	0 78	550
40	2.76	25	0.88	132	0.73	1 720

tion require some correction.

Mean values of maxi

induced by driving wheels of each locomotive at the speed of 60 km. per

KIND OF LOCOMOTIVE.	Type of locomotive.	CU			
		Vertical bending stress			
		Outer rail.		Inner rail	
		Stress (kgr./cm²)	Increase (°/o).	Stress (kgr./cm²).	Inc (°
Steam locomotive :					
With tender	D 50	949	50	881	
Do.	9 600	1 156	71	940	
Do.	C 51	1 035	71	1 197	
Do.	C 52	997	70	1 183	
Do.	8 850	1 028	64	975	
Do.	8 620	1 282	63	1 026	
Do.	6 760	1 287	44	966	
Tank	4 100	936	61	777	
Mean	...	1 084	62	993	
Electric locomotive :					
Nose-suspension — With leading trucks	ED 53	1 043	76	1 033	
	EF 52	1 068	94	926	
Nose-suspension — Mean	...	1 056	85	980	
Nose-suspension — Without leading trucks (mean)	ED 51	1 321	51	1 243	
B. B. C. individual axle drive (mean)	ED 54	1 027	71	1 033	

Remark : 1. As the centre peg of the deflectionmeter moves slightly due to vibration of earth, the test results
2. Horizontal deviation for both rails appeared in outward direction from the track center.

ses and deviations

heir per cent increase as compared with those of the locomotive at rest.

K (radius 600 m. = 30 chains).

Horizontal bending stress.			Vertical deviation of rail.				Horizontal deviation of rail head.			
uter rail.	Inner rail.		Outer rail.		Inner rail.		Outer rail.		Inner rail.	
Increase (°/o).	Stress (kgr./cm²).	Increase (°/o).	Deviation, millimetres.	Increase. (°/o).	Deviation, millimetres.	Increase. (°/o).	Deviation, millimetres.	Increase. (°/o).	Deviation, millimetres.	Increase. (°/o).
82	153	—39	3.73	37	3.36	18	1.51	231	0.84	6
57	250	—12	3.61	43	3.41	21	1.72	110	1.18	16
61	365	17	3.39	11	3.58	—1	2.39	87	0.95	—23
214	306	— 8	3.40	10	3 48	—9	2.40	200	0.82	—15
78	265	— 4	3.53	26	3.11	8	1.57	107	0.55	—17
28	353	18	3.33	21	3.11	13	2.47	180	1.02	5
50	246	—28	4.31	30	3.99	9	1.72	274	0.62	19
—6	230	8	4.41	24	3.54	9	2.25	104	0.81	—12
71	271	— 6	3.73	25	3.45	9	2.00	162	0.85	— 3
405	134	—23	3.66	11	3.61	16	1.19	37	0.92	37
105	218	28	3.49	30	3.24	—3	1.10	67	0.78	9
255	176	3	3.58	21	3.43	7.5	1.15	52	0.85	23
231	188	14	3 80	16	3.41	10	0.77	40	0.75	30
88	241	—26	3.50	18	3.38	4	1.67	150	0.86	—17

ation require some correction.

Mean values of maxi

induced by driving wheels of each locomotive at the speed of 60 km. per

KIND OF LOCOMOTIVES.	Type of locomotive.	CU			
		Vertical bending stress.			
		Outer rail.		Inner ra	
		Stress (kgr./cm²).	Increasse °/o.	Stress (kgr./cm²).	In (
Steam locomotive :					
With tender	D 50	927	71	918	
Do.	9 600	875	63	913	
Do.	C 51	942	86	911	
Do.	C 52	840	73	998	
Do.	8 850	927	91	807	
Do.	8 620	1 104	63	843	
Do.	6 760	837	58	732	
Tank	4 100	808	65	604	
Mean	...	908	71	841	
Electric locomotive :					
Nose-suspension: With leading trucks	ED 53	905	59	852	
	EF 50	893	64	786	
Nose-suspension: Mean	...	899	62	819	
Nose-suspension: Without leading trucks (mean)	ED 51	1 129	52	1 160	
B. B. C. individual axle drive (mean)	ED 54	847	60	992	

Remark : 1. As the centre peg of the deflectionmeter moves slightly due to vi

2. Horizontal deviation for both rails appeared in outward directio

ses and deviations

heir per cent increase as compared with those of the locomotive at rest.

ζ (radius 400 m. = 20 chains).

Horizontal bending stress.					Vertical deviation of rail.				Horizontal deviation of rail head.			
ıter rail.		Inner rail.		Outer rail.		Inner rail.		Outer rail.		Inner rail.	
s ı²).	Increase (°/o).	Stress (kgr./cm²).	Increase (°/o).	Deviation, millimetres	Increase (°/o).	Deviation, millimetres.	Increase (°/o).	Deviation, millimetres.	Increase (°/o).	Deviation, millimetres	Increase (°/o).
	140	223	62	4.68	32	3.63	13	1.20	76	1.18	— 30
	29	338	98	4.70	38	3.54	11	1.62	34	1.58	— 27
	138	426	82	4.39	17	3 64	—2	1.21	147	1.45	— 17
	164	533	89	4.52	18	3.97	5	1.30	44	1.58	— 17
	86	257	145	4.63	35	3.45	7	1.79	118	1.50	— 33
	61	228	13	4.53	31	3.60	12	1.74	72	1.97	+ 7
	59	291	32	4.40	23	3.92	8	1.27	69	1.54	— 16
	66	212	1	4.72	20	3.83	6	2.26	34	1.59	— 20
	93	314	65	4.57	27	3.70	8	1.55	74	1.55	— 19
	120	175	46	4.72	17	3.94	11	1.18	44	1.11	— 28
	113	307	94	4.41	20	3.70	3	1.23	84	1.45	— 4
	117	241	70	4.57	18.5	3.82	7	1.21	64	1.28	— 16
	71	351	97	5.17	18	3.61	6	1.26	75	1.36	— 5
	163	399	63	4.48	15	3.71	2	1.14	92	1.26	— 39

, the test results about the deviation require some correction.

k center.

maintaining a correct track gauge than in the case of steam operation, owing to the fact that rail alignment is more liable to damage by the electric locomotive than by the steam locomotive. On the other hand, there may be some parts of track which require less attention for electric operation than for steam operation.

Our experience so far proves that electric operation has not brought much difficulty into track maintenance and, furthermore, it indicates that maintenance will become the easier as we get the more experienced in suitably maintaining the track for electric operation.

Shortly after the electrification, the 37-kgr. (74.6 lb. per yard) rail was replaced by the 50-kgr. (100.8 lb. per yard) rail, but it is a fact that this change was made entirely on account of increased traffic and speed, and is quite independent of the problem of the change from steam operation to electric operation. Thus the effect of the electric locomotives upon the maintenance of the track is not yet clearly known. Of course, this rail replacement is an aid toward obtaining a sufficient area for the return circuit. From our experience, we learn that the locomotive of nose-suspension type without leading trucks has a more serious effect upon the maintenance of the track than the steam locomotive. In fact, we believe that the increased difficulties in track maintenance are chiefly due to the use of electric locomotives of nose-suspension type without leading trucks, and it happens in our actual operation that more of these are employed than those of leading truck type. But so far as the locomotive itself is concerned, we have found no defects in this type, and we are now satisfied with our present electric operation.

The electric locomotive of nose-suspension type is quite simple in construction. Moreover, it provides ample room for the machinery and apparatus necessary in direct current locomotives. This aids not only the design and construction of the locomotive, but also makes easier the inspection and repair of the locomotive parts, a very important item to insure reliability in the locomotive.

Thus the electric locomotive of nose-suspension type with leading trucks can be recommended as a very good type in general, and the locomotive without leading trucks is adaptable for slow speed operation.

Further, it must be borne in mind that the weight on the driving axle should be kept as light as possible for the locomotive of the nose-suspension type.

With the collective drive type electric locomotive, its effect upon track is rather better than that of the steam locomotive — due to the lack of the excess balance weight.

Our experience so far relative to the individual axle drive of B. B. C. type is that it is excellent, particularly on straight track. This type of drive is good from the theoretical point of view, but in any design of this kind its construction is rather complicated. But every effort is being made to better the construction, and several new designs of this type are appearing. It is hoped that their arrangement of machinery and apparatus will be made in such a way that the inspection thereof will be carried out more easily. There is a growing tendency to use this type of drive, especially in high speed locomotives.

4. — Effect of leading truck wheels upon the maintenance of locomotives and tracks.

For passenger service, the common practice is to equip steam locomotives

with a leading truck. Even for freight service, this is the general practice in the U. S. A., and often in Europe. On the Japanese Government Railways the custom is to use leading trucks on almost all locomotives — which serves to eliminate excessive flange wear.

The electric locomotive of the collective drive type is similar in construction to the steam locomotive. Therefore, the experience gained in the operation of steam locomotives may well be applied to this type of electric locomotives. Electric locomotives of the individual axle drive type of the Brown Boveri Co., and others, may also be considered similar to the steam locomotive in their wheel arrangement or in the relation between the wheels and the rail. On the contrary, opinions differ in the case of electric locomotives of the nose-suspension type as to leading truck wheels. As a matter of fact, electric motor cars are not equipped with a leading truck, even though they run at a very high speed. That the truck of the motor car behaves as a bogie or the leading truck of the steam locomotive, independent of the motion of the car body, is the reason that leading trucks are not used for electric car trucks. But it is often found that the flange wear of the wheels of the electric car is greater than that of the passenger car or that of the leading truck of the steam locomotive. This may be attributed to the fact that the motor car truck is mounted with heavy motors and, therefore, the reaction against the rail is greater, and also each pair of wheels can not slip freely, independent of another pair of wheels.

In case of the electric locomotive of the nose-suspension type, the weight of the motor is usually heavier than that of the motor car and, moreover, the driving wheels of the locomotive are much more restrained in their free movements by reason of the draft action of the trailing load than are the wheels of the motor car — and thus the flange wear of the wheels is inevitably a more serious factor in the case of electric locomotives.

Actual examples show that the electric locomotive of the nose-suspension type assigned for high speed express service is equipped with the leading truck, while many locomotives employed in medium speed service are not. Some of our electric locomotives for medium speed service have leading truck wheels, and some not. Comparative tests relative to the tire wear of the two types of locomotives were made on our Railways. The wear of the tread and the flange of the tire, both for the leading wheels and for the driving wheels, per 10 000 km. run, are given in table 6 (see page 1710), and their worn form in figure 9.

The difference in the wear on the tire flange of the driving wheel is clearly shown in favour of the locomotive having truck wheels. There may be a greater difference in flange wear if the leading truck behaves well — as our experience has shown to be the case with steam locomotives. The flange wear of the leading truck wheels may not be serious, because they may be turned independently of the other wheels, but the driving wheel tires should be turned so as to keep all the driving wheels in the same diameter. The tire flange wear of a locomotive has, of course, its effect upon the maintenance of the track. Moreover, the result of the experiments with the locomotive types described in the previous chapter shows that the electric locomotive of nose-suspension type with a leading truck gives much less values in the stress and deviation of rail induced by their driving wheels than the type without a leading truck. The lighter axle load of the former may be another cause which helps to

TABLE 6.

Wear of tires of electric locomotives

with and without leading trucks after 10 000 km. running of the locomotives.

LOCOMOTIVE.	Locomotive. No.	Wheel arrangement.	Kind of wheel.	Mean wear of tread (millimetres).	Mean wear of flange (millimetres).
Without leading trucks.	ED 502	B + B	Driving wheel.	0.198	0.280
	ED 5016	B + B	—	0.159	0.222
	ED 525	B + B	—	0.282	0.270
	(Mean)	—	—	0.213	0.257
With leading trucks . .	ED 534	IB + BI	Leading wheel.	0.348	0.103
	(Mean)		Driving wheel.	0.296	0.024
	ED 541 (1)	I D I	Leading wheel.	0.195	0.254
	(Mean)		Driving wheel.	0.097	0.146

(1) This is the individual axle drive type and therefore the test result is given only for reference.

produce this result. It is difficult, however, as already mentioned, to obtain clear knowledge as to the effect of these stresses and deviations of rail upon the maintenance of track. But it can be said that, the less stress and deviation there is, the better for the maintenance of the track.

Of course the construction of the electric locomotive becomes more complicated if it is equipped with a leading truck. Especially difficult is it to design a good single axle leading truck for electric locomotives of nose-suspension type — due to the lack of space for the radius bar. And it may be added that the increase of such mechanical parts will have comparatively little effect upon the cost of manufacture.

Concerning this problem of leading trucks, the Metropolitan Company of England advised us that no particular effects had been noticed by their use, while the Canadian National Railways advised us that they had no experience, but would recommend the use of a leading truck.

Thus we conclude that the leading truck may be recommended as part of the equipment for electric locomotives intended for both high speed and medium speed services.

5. — Arrangement of machinery and apparatus.

The locomotive body is usually of the box type with double end cabs, though steeple type with a central cab is sometimes used, especially for locomotives used in shunting.

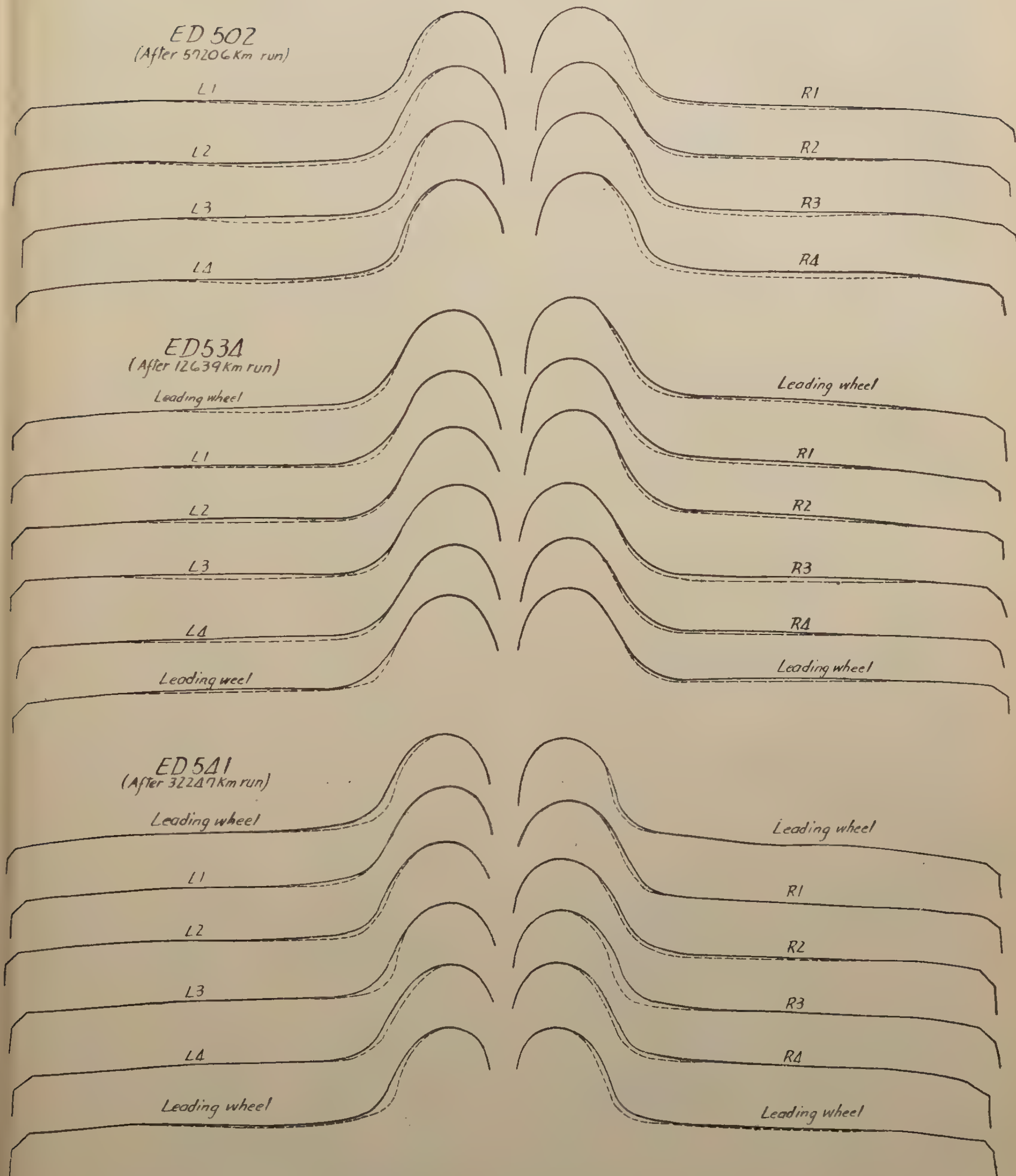


Fig. 9. — Tire profile (———— Original .... After wear).

Generally, the box type body affords ample room for the machinery and apparatus of locomotives of the nose-suspension type. But even if there is room enough it is somewhat difficult to arrange the machinery and apparatus in good order so that they will fulfil the following conditions :

a) Easy for handling and inspection.

b) Protection against breakage, and to limit such breakage to as small an extent as possible.

c) Good lighting, and sufficient ventilation.

d) Balancing of weight distribution.

e) Convenience for erecting and dismounting.

f) Heat generated in the rheostat to be easily drifted to the open air.

g) Protection against rain or moisture entering the room.

But before considering the arrangement of machinery and apparatus, the arrangement of the corridor must be considered. There are three methods of corridor arrangement, i. e., the central corridor, one side corridor, and corridors on each side, each type having its merits and demerits.

a) Central corridor type. — With only one corridor, the floor space can be very well utilized in the arrangement of machinery and apparatus. The starting rheostat and the high and low tension electric equipment are located in compartments along both side walls — and this arrangement is liable to damage the electrical equipment by the unavoidable intrusion of more or less rain and moisture into the compartment through louvres and windows.

The arrangement is convenient for the rheostat to dissipate the generated heat. The inspection of the apparatus along the side walls, especially the back side of them, is almost impossible. Therefore, this arrangement cannot be considered a good one, and should be adopted only when the floor space is not sufficient for any other arrangement.

b) Also, the second arrangement, or one side corridor type, is not a good one, because it does not afford facilities for inspection, and, moreover, a good balance of weight distribution cannot be expected in this type.

c) The third arrangement provides for a corridor on each side. With two corridors a considerable part of the floor space is taken up, the result being that some of the apparatus has to be installed over other apparatus or machinery, but as all equipment is located away from the side walls, the window and louvre areas can be made sufficiently large without causing damage to the apparatus through moisture and rain. Also large windows provide a good light for inspection. If in addition to the side corridors we can provide a small central passage through the high tension and rheostat compartments, all apparatus will then be readily accessible and can be thoroughly inspected from each side.

As this method of arrangement seems the best of the three, we have adopted it for our new electric locomotive type EF 52. The arrangement of machinery and apparatus in this locomotive is shown in figure 10.

As is seen from the drawing, the high tension room, enclosed by wire netting, has been located in the centre. Unit switch contactors, high-speed circuit breaker, reverser, fuses, relays, etc., are arranged in this room. Rheostats are separated into two groups, each group being installed in the enclosed chamber

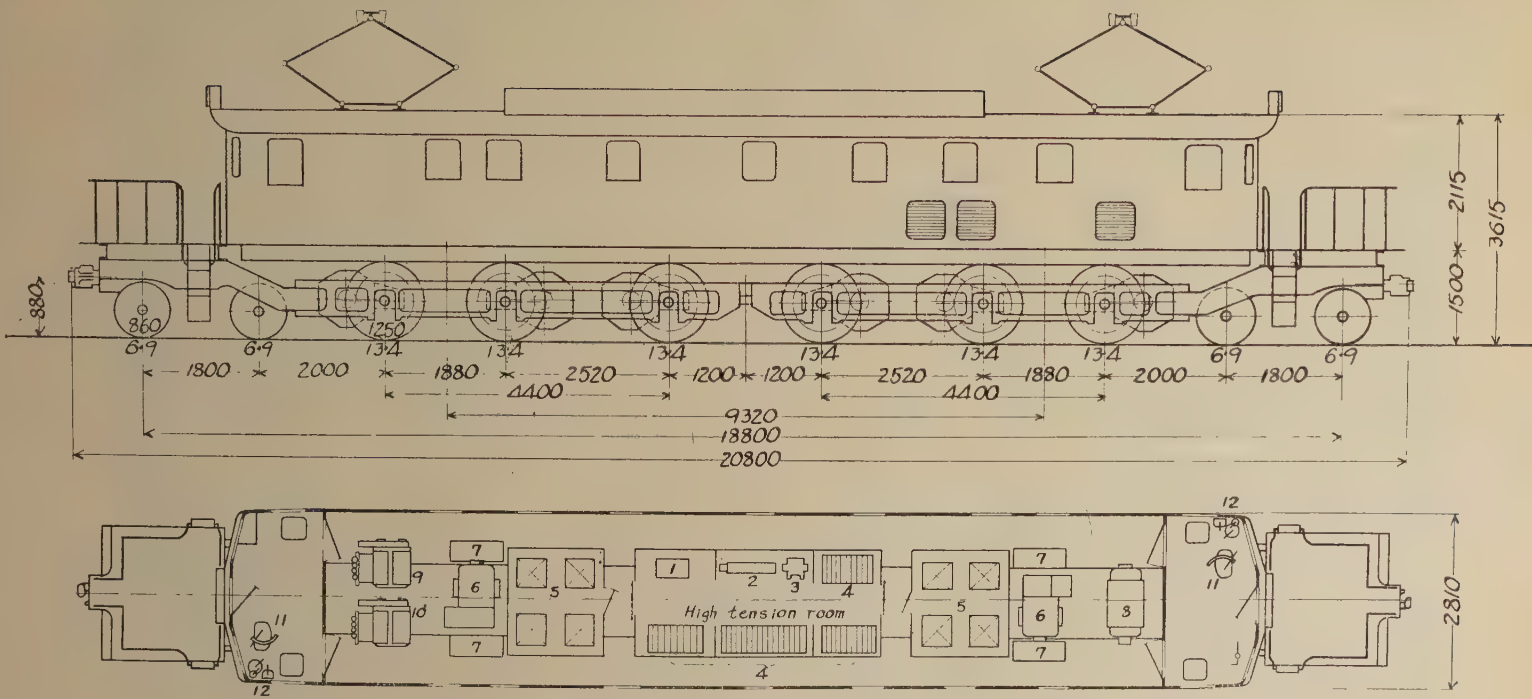


Fig. 10. — Electric locomotive, type EF 52, Japanese Government Railways.

Explanation :

1. Lightning arrester.
2. High-speed circuit breaker.
3. Reverser.
4. Contactors.
5. Rheostat chamber.
6. Blower.
7. Battery.
8. Motor-generator.
9. Vacuum pump.
10. Air compressor.
11. Master controller.
12. Brake valves.

situated adjacent to the high tension room.

The reason that the rheostats were arranged in two groups was the desire to obtain the best balancing of the weight of the cab, as well as to effect easy connection between the rheostats and the unit switch contactors. The rheostat room has ventilating holes through the floor, the cooling air passing from these holes into the open air through a monitor by natural ventilation.

There are two ventilating fans, each of them installed adjacent to the rheostat room. Each fan furnishes cooling air to the traction motors mounted on the truck. The space between the centre sill of the underframe was utilized as the air duct for the cooling air. Attention has been given to the arrangement of the air duct so as to provide sufficient openings for the purpose of inspecting the traction motor.

In the cab, the master controller, brake valves, switches, and other apparatus must be arranged in a convenient position for operation. The master controller and the brake valves must also be so placed that they may be easily handled in shunting service.

6. — Control equipment.

Control equipment is as important as the traction motor, even a small defect in it being liable to cause serious accidents. Therefore, such equipment must be designed and constructed with every possible care. From our experience, we deduce the following three problems — which should be carefully considered :

a) *Safety device for the main circuit.* — Is it enough to provide a fuse only, or is it necessary to install a high-speed circuit breaker?

When, due to a short circuit, an extreme current flows in the circuit of a locomotive, the damage to the locomotive will be severe, especially if the circuit is complicated, and it will be severer if the power supply source is large. It is, therefore, of the utmost importance that the locomotive should be cut out (in the event of a short circuit) from the main circuit as quickly as possible. For this purpose a fuse is used in connection with the line contactors or a line breaker, though sometimes a circuit breaker, or a high-speed circuit breaker, is used.

According to our experience, fuse protection is not reliable enough to insure the protection of the breaker or contactors, and other apparatus located nearby, from the extreme current, and, therefore, big damages result, especially if the high tension d. c. system is used. In fact, the proper design for a fuse with ample capacity for a big locomotive is a difficult problem, and the use of the fuse alone sometimes makes the effect of a short circuit more serious.

An ordinary circuit breaker is not sensitive enough for this purpose, and, therefore, it is also unreliable.

So far as we have learned, there is no better way to eliminate the damage caused by a short circuit than to install a high-speed circuit breaker in addition to the line breaker, on each locomotive using high voltages. There may be an opinion that the high-speed circuit breaker should be used in the substation or in the switching station, and that the usual line breaker is sufficient for the locomotive but the purpose of the high speed circuit breaker in the substation or the switching station is to protect the machinery and apparatus in the station, and, therefore, it is usually adjusted to act with a larger current than that for which the high-speed circuit breaker in each locomotive

is adjusted. If it is otherwise adjusted, much more disturbance will occur if the power supply is cut off from all the locomotives on the line.

When a locomotive is provided with a high-speed circuit breaker it can be advantageously utilized in connection with overload relays, acting in case of an overload. Thus the line contactors, or a line breaker, are well protected.

After experiencing much locomotive trouble, the Japanese Government Railways equipped all electric locomotives with the high-speed circuit breaker, with the result that such troubles were diminished in a remarkable degree;

b) Which is the most preferable, the unit switch control, cam shaft control, or the combination thereof?

The unit switch control seems to be most extensively used on d. c. locomotives. Being a small unit of simple construction, the unit switch control has the merits of being economical in the utilization of space, ease of inspection, and low cost in manufacture and maintenance. Moreover, in breaking capacity it is superior to the cam shaft control, but the unit switch control may be inferior to the cam shaft control in insuring the sequence in exact degrees. We have adopted the unit switch control system in our new locomotive, type EF 52, equipped with six motors. When all the electrical parts were completed we made the load and sequence test for both the motors and the control equipment. These tests were made in the shop of the Hitachi Engineering Works, the electrical equipment being placed as shown in figure 11, the manner in which each apparatus acted being easily seen.

In some cases the sequence was not exact enough. We found that such faults were caused by the copper powder on the insulating segments of the main drum of the master controller and were produced by the friction between fingers and segments. These faults were eliminated by making a groove between the copper segments and insulating segments. Of course in actual practice we have had no such trouble since this equipment was placed on the locomotive, but the result of these tests shows that the unit switch control may not be exact enough and is probably inferior to the cam shaft control so far as the sequence is concerned.

The cam shaft control does not need the interlocking device, and it gives an accurate action. The whole device can be made compact in size. We are using this type of control extensively on the motor cars, with satisfactory results. But in construction this system is rather complicated. It lacks the interchangeability of the elements of the equipment, and the breaking capacity is rather low.

The third system, incorporating features of both the other systems, may now be considered. The cam shaft control is applied to combination switches of the main motors whose sequence of action must be quite exact, while the unit switch control is applied to switches for cutting in and out of the main circuit (line contactors for instance), and for combining the rheostats. Though we have not yet adopted this system, we believe that such combination may be recommended as the best.

c) *Sudden cut off of the main circuit.* — In the main circuit of the locomotive, some resistance is generally inserted to decrease the main current before it is cut off. But we have several locomotives in which heavy current is cut off directly without inserting any resistance in the main circuit. By this sudden cut off, an abnormal voltage rise is induced in the

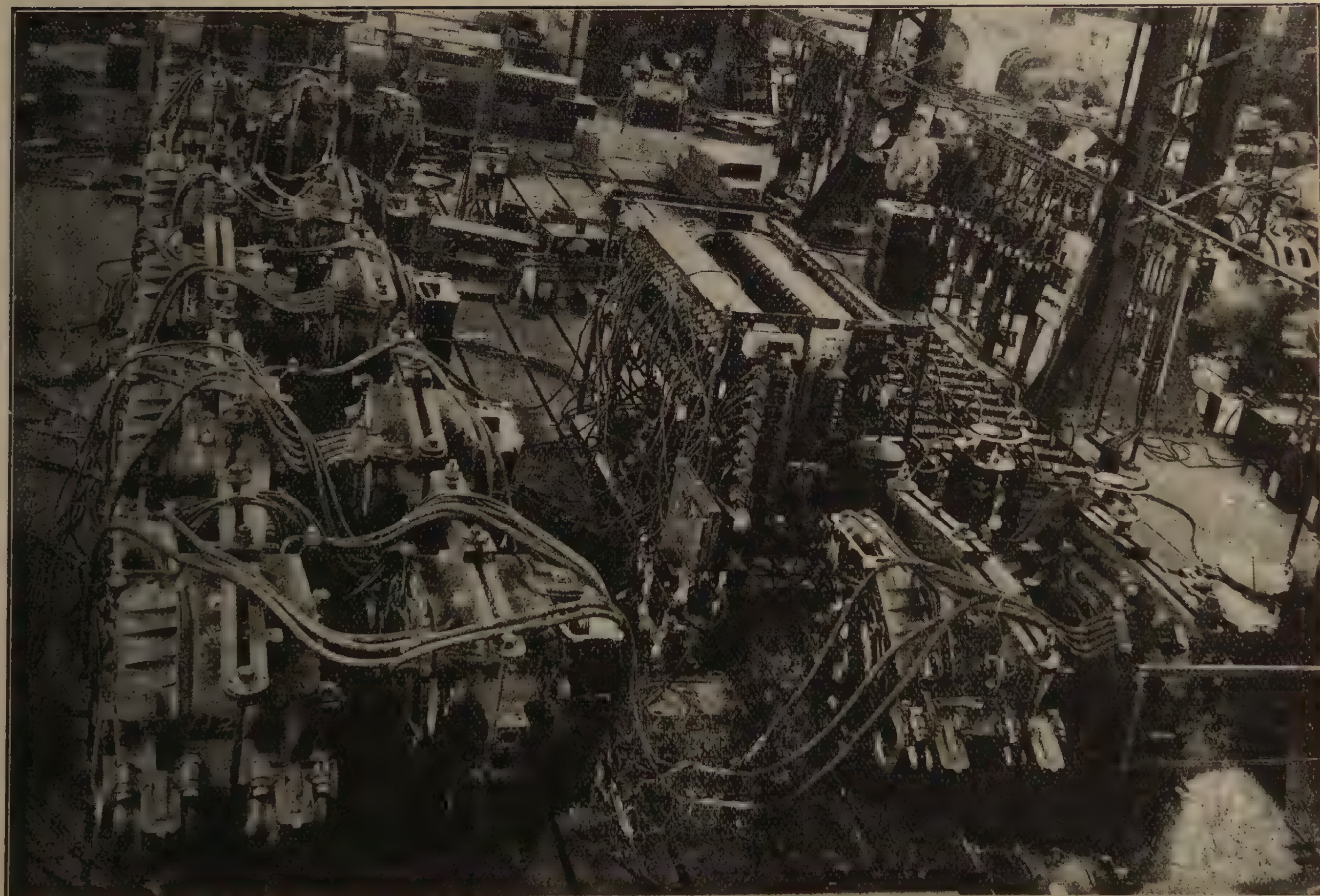


Fig. 11.

line, and we found that the surge voltage was notably high, as will be afterwards described. This surge voltage may have no serious effect upon the equipment, but we find it desirable, for the sake of insuring safety, to insert some resistance before breaking the main circuit.

7. — Method of voltage regulation of motor-generator set for control service.

Usually a motor-generator set is used in the high tension locomotive for supplying the control and lamp currents. Though it is less important to keep the lamp circuit voltage constant for locomotives than for electric cars, it is still desirable to limit the voltage regulation of the control circuit to a certain amount, for the sake of insuring the positive action of the control equipment, even if the line voltage varies in a wide range. If a high-speed circuit breaker is provided, as we have recommended, it becomes more important to limit the voltage variation of the control circuit to a smaller amount. As the high-speed circuit breaker is a safety device for the control equipment it is desirable, when the control circuit voltage drops, that it shall act before the action of any apparatus of the control equipment becomes uncertain. That is to say, the limitation for the voltage variation of the holding coil of the high-speed circuit breaker must be more precise than for the usual control equipment. Moreover, it is difficult to adjust the high-speed circuit breaker for proper action with the normal, and the dropped control circuit voltages without injuring its important property of breaking the main circuit as quickly as possible when the main current attains a certain limit. It is desired, therefore, to limit the voltage variation of the control circuit within 20 % of the normal voltage. As the voltage of the main circuit often varies from 30 to 40 %, a motor-generator set of special design is required to secure a constant voltage, irrespective of the line voltage. Several kinds of these sets may be grouped into the following classes :

1. *System with voltage regulator.*
2. *Self-regulating system.*

A short description of each system is given hereafter.

1. *System with voltage regulator.* — Usually the motor is compound and the generator is shunt wound, and the shunt field current of the generator is controlled by the regulator described below :

a) Using a Tirrill regulator (fig. 12). Certain resistance is in series with the shunt field of the generator, and a part of the resistance is thrown in or out with high frequency by means of a vibrating contact which is operated by a coil connected between terminals of the generator;

b) Modification of the method (*a*) (fig. 13). A small separately excited counter-electromotive force motor instead of the resistance mentioned in method (*a*), loaded with a fan for damping, is in series with the shunt field of the generator, and the separate field of the counter-electromotive force motor is energized and de-energized alternately in high frequency, by means of vibrating contact which is operated by the terminal voltage of the generator.

These systems (*a*) and (*b*) are effective in getting very satisfactory voltage regulation, but the delicate construction of the regulator is not adapted for railway service;

c) Using a carbon pile regulator (fig. 14). A carbon pile resistance, used for series resistance of the shunt field

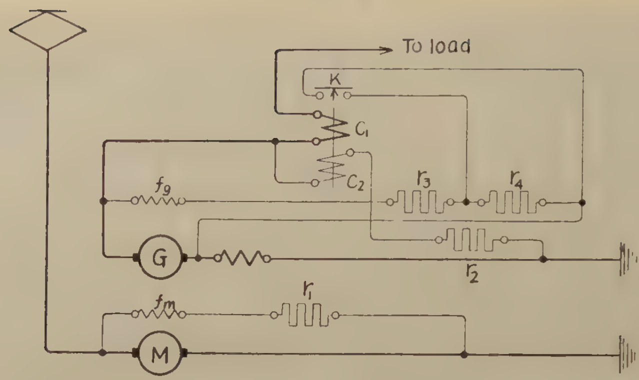


Fig. 12.

M. Shunt motor armature.
G. Shunt generator armature.
fm. Shunt field of motor.
fg. Shunt field of generator.
K. Vibrating contact.
r_1 Series resistance for motor shunt field.
r_2. Series resistance for coil C_2.
r_3. Series resistance for generator shunt field
r_4. Series resistance for generator shunt field which is put in and out by vibrating contact K.
C_1. C_2. Operating coil for the vibrating contact K.

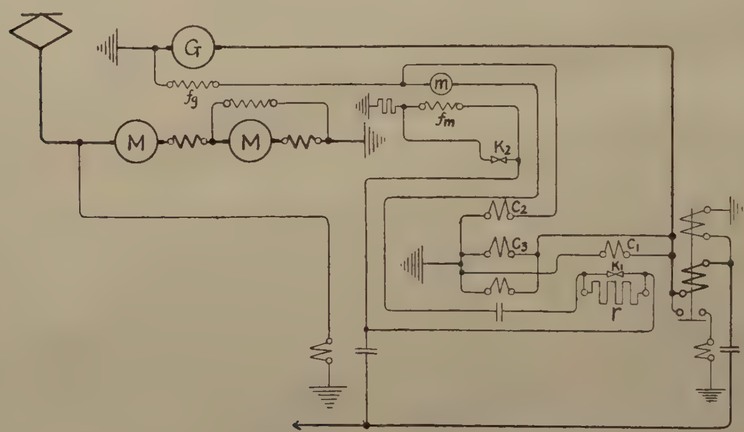


Fig. 13.

M. Motor armature.
G. Generator armature.
m. C. e. m. f. motor armature.
fg. Shunt field of the generator.
fm. Separate field of the c. e. m. f. motor.
r. Series resistance for shunt field of the generator.
K_1. Vibrating contact for series resistance (r) of the generator field.
K_2. Vibrating contact for field (fm) of the c. e. m. f. motor.
C_1. Operating coil for K_1.
C_2. C_3. Operating coil for K_2.

circuit of the generator, is controlled by mechanical pressure on the carbon pile acting electro-magnetically, depending upon the terminal voltage of the generator. This system is suitable for small capacity and low voltage, as 1 *kw.* set of 32 v.

2. *Self-regulating system.* — The gene-

rator does not have a separate voltage regulator. The following apparatus, etc. belongs to tis system;

d) Motor-generator set having an exciter for the motor mounted on the same shaft (fig. 15). In this system the motor has two field windings. One of them is in series with the motor armature, the other is excited from the exciter. The exciter has two field windings, — one is the shunt field of the exciter, and the other is in series with the motor armature and field. The speed regulation can be kept within a very small range for the wide variation of the line voltage. The generator has a compound field for regulation against the variation of the load.

The advantage of this system is in its good voltage regulation in comparison with other self-regulating motor-generator sets;

e) Using saturated and unsaturated poles for the generator (fig. 16). The compound wound motor is provided with distributed compensating winding and main field winding. A special exciting brush is provided on the generator commutator for electrically shifting 90° from the main brush, and the saturated and unsaturated fields are excited between this brush and the main positive brush. The superposed field strength of these two fields can hold nearly constant voltage of generator for the variation of the line voltage and load. This system affords only a rather inferior voltage regulation and commutation of the generator;

f) With a special auxiliary generator (fig. 17). In this system the generator and motor are ordinary plain shunt wound. The auxiliary generator armature winding is placed in the same slot of the motor armature winding and its commutator is mounted on the other side of the motor commutator. The main generator and auxiliary generator are connected in series, but opposite in polarity;

g) Generator field is excited in series with the motor armature (fig. 18). The motor has compound fields, one excited in series with the motor armature, the other excited from the generator. The generator field is also compound, — one is excited in series with the motor armature and field, and the other is of ordinary shunt excitation. In this system inferior voltage regulation and commutation of motor are unavoidable when sudden voltage change occurs.

In actual service we are using all the motor-generator sets previously mentioned in (*f*). While all are applicable to railway service, some are superior to others. In general, motor-generator sets having the voltage regulator are superior in their voltage regulation to those of the self-regulating type. But the delicate construction of the voltage regulator is not adapted for railway service. The motor-generator set having an exciter on the same shaft [described in (*d*)] is the most desirable for railway service if good voltage regulation and its solid construction are considered.

8. — Troubles of traction motors and their remedies.

As shown in tables 7 and 8, we have many troubles with traction motors, but during recent years they have been markedly reduced by introducing improvements in design, materials, etc. As will be noted in the tables, the essential faults are as follows :

1. Faults in the armature coil.
2. Breaking of the bind wire.

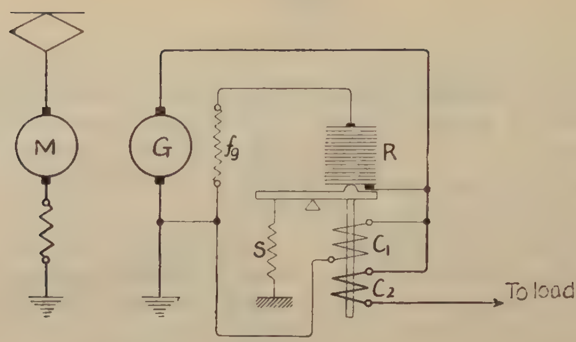


Fig. 14.

M. Motor armature (with blower on the same shaft).
G. Generator armature.
fg. Generator shunt field.
R. Carbon pile resistance (series with *fg*).
C_1. Operating coil of the regulator (in shunt).
C_2. Operating coil (in series with load).
S. Counter spring of coil C_1 and C_2.

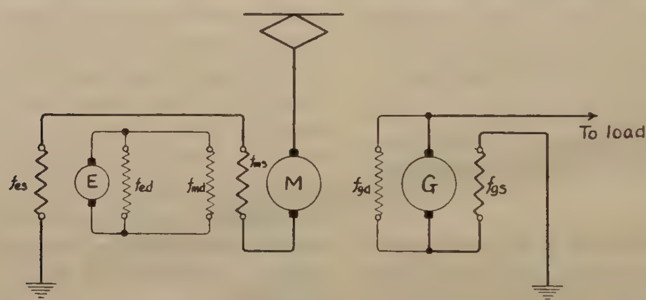


Fig. 15.

M. Motor armature.
G. Generator armature.
E. Exciter armature.
fms. Series field of motor.
fmd. Separate field of motor.
fed. Shunt field of exciter.
fes. Separate field of exciter.
fgd. Shunt field of generator.
fgs. Series field of generator.

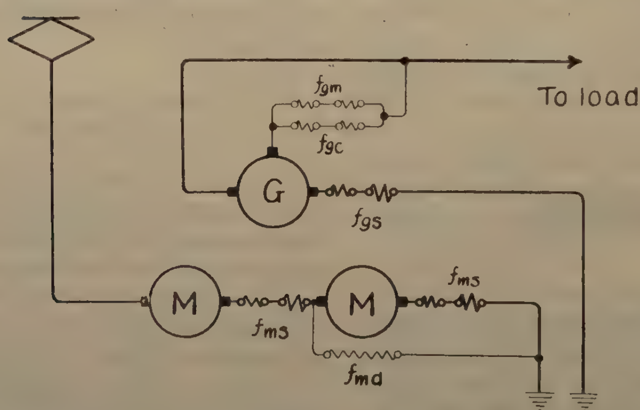


Fig. 16.

M. Motor armature.
G. Generator armature.
fms. Motor series field.
fmd. Motor shunt field.
fgc. Generator series field.
fgs. Generator cross field.
fgm. Generator main field.

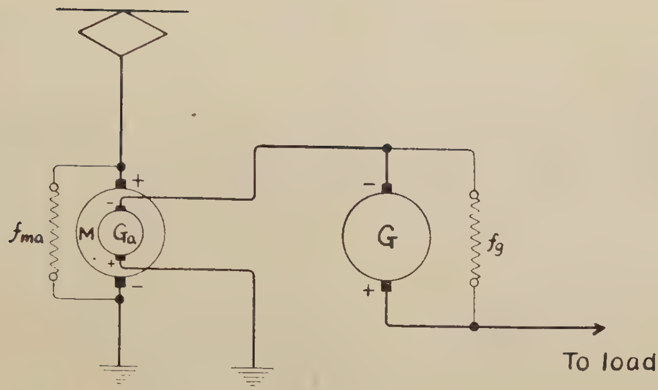


Fig. 17.

M. Motor armature.
G. Generator armature.
Ga. Auxiliary generator.
fma. Field for motor and auxiliary generator.
fg. Generator field.

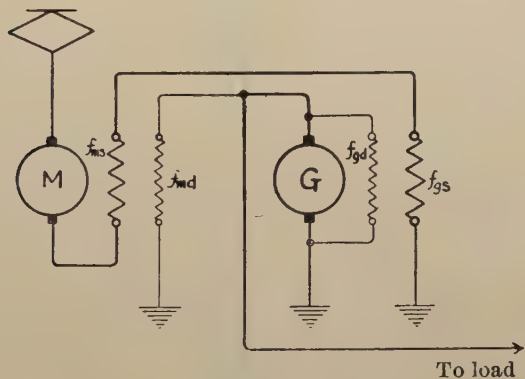


Fig. 18.

M. Motor armature.
G. Generator armature.
fms. Series field of motor.
fmd. Separate field of motor.
fgs. Separate field of generator series with the motor armature.
fgd. Shunt field of generator.

3. Faults in the field coil.
4. Flash-over of the commutator.
5. Faults in the brush-holder.

1. In our case the causes of faults in the armature coil are mostly grounds or short circuits, and these faults have been greatly reduced by the strict selection of the insulating material and by the careful treatment of the armature coil.

2. The faults in the bind wire are due to poor material, to overheating by eddy current induced in itself, or by improper handling of the wire, but they can also be reduced by selecting better material and by its better treatment.

TABLE 7.

Troubles of traction motors in electric locomotives.

Parts. — Faults.	Number of faults. — Year.			
	1925.	1926.	1927.	1928.
Armature :				
Armature coil burned out	...	...	1	...
Bind wire broken	1	...	3	1
Bearing overheated	12	5	2	2
Shaft and gear broken	...	3	2	10
Others	..	2	1	...
Commutator :				
Flash-over	15	27	9	1
Loose conductor in riser	...	...	...	1
Field :				
Field coil burned out	...	..	1	...
Grounds in field coil	...	1	1	9
Brush-holder :				
Brush broken	...	...	...	1
Others	3	...	...	...
Total	31	38	20	25
Locomotive run per year (kilometres)	384 382.6	1 266 032.9	2 942 320.6	3 113 407.
Number of motors	188	260	272	314
Number of faults per motor per year	0.17	0.14	0.07	0.08
Number of faults per 1 000 000 locomotive-kilometres	83.3	30.0	6.8	8.0

TABLE 8.

Troubles of traction motors in motor cars.

Parts. — Faults.	Number of faults. — Year. 1924.	1925.	1926.	1927.	1928.
Armature :					
Short circuits } of armature coil	24	14	18	7	8
Burning out } of armature coil	137	150	42	23	19
Grounds } of armature coil	170	98	38	53	47
Broken circuits } of armature coil	...	3	3	21	14
Bind wire broken	83	93	67	75	71
Cloth band broken	...	...	10	7	4
Blower blade broken	...	...	3	9	6
Broken shaft and loose shaft	...	...	...	6	1
Others	37	37	6	5	6
Field :					
Short circuits } of field coil	...	...	2	1	...
Burning out } of field coil	198	125	20	34	27
Grounds } of field coil	188	155	80	82	58
Grounds in connecting wire	...	...	19	37	12
Others	6	4	2	2	8
Commutator :					
Short circuits	8	2	...	...	...
Grounds	25	5	...	...	...
Flash-over	1 038	321	53	81	141
Loose conductor in riser	...	1	17	11	15
Others	2	11	...	1	10
Brush-holder :					
Grounds	2	37	100	71	99
Spring broken	...	...	23	21	3
Porcelain broken	...	...	4	2	44
Others	...	30	15	22	26
Others :					
Electrical part	4	84	11	13	4
Mechanical part			44	77	57
Total	1 922	1 170	577	661	680
Total number of main motors	1 261	1 226	1 216	1 435	1 440
Motor car run per year (kilometres)	11 673 545.4	12 860 895.9	15 070 271.3	19 470 241.5	29 522 546.5
Number of faults per motor per year	1.523	0.955	0.474	0.460	0.472
Number of faults per 1 000 000 kilometres run	164.7	91.0	38.3	33.9	23.0

3. The faults in the field coil are also grounds or short circuits caused by the lack of proper insulation and the intrusion of bearing oil, brake-shoe dust and other foreign matter wich enters through the air ventilating inlet. We are now suffering from these faults, because it is most difficult to absolutely prevent bearing oil and brake-shoe dust from entering.

4. The flash-over of the commutator is caused by a broken circuit in the armature coil or the commutator, by defects in the design of the brush-holder, by unsuitable material in carbon brushes, and especially by the vibration of brushes, which, in our case, is caused by the vibration of the truck. For instance, for several years we have had a lot of flash-overs of commutators in locomotive types ED 50, 51, 52, and EF 50, in which the truck vibrations are very severe. However, these faults have been reduced by replacing the locker of the brush-holder with one of more solid construction — which shows that these faults were largely caused by the vibration of the brushes. The effect of the carbon brush composition upon the commutator is not yet known.

5. In our case, brush-holder faults are caused principally by defects in the insulated support of the brush-holder, but they will soon be eliminated simply by replacing the support with one specially treated. Side wear of carbon brushes is sometimes the cause of the flash-over. The wear may be caused by the lack of pig-tail, or it may be due to brake-shoe dust, or to both of them. Speaking generally, we have many troubles with the insulation of electrical equipment. Frequent heavy rains and high humidity in Japan may largely affect the insulating properties of the insulating material.

In fact we have much trouble with the insulation of the electrical equipment in our imported locomotives. We have learned that in the countries from which they came the insulation troubles are far less.

Therefore, as so much trouble is caused by insulation faults, it is most important that the high-speed circuit breaker should be installed for the purpose of minimizing damage as much as possible, as stated before.

9. — Surge voltage.

To investigate the manner in which surge voltage is induced in the line at the instant when the current of the locomotive is suddenly cut off, a test was made in 1926 by the Japanese Government Railways on the section between Shinagawa and Yokosuka. This section is shown in figure 19. On the test, two trains were operated; the leading train of 240-ton load was pulled by an electric locomotive. The other electric locomotive train followed, keeping a headway of seven minutes for the leading train.

The abnormal voltage rise in the power line induced by the sudden breaking of the current of the leading train was measured with gap-voltmeters arranged on that train's trolley and motor sides and also on the trolley side of the following train — the connection of which is shown in figure 20.

Moreover, the same voltage rise was measured at the pre-determined time with oscillographs placed at the Tsurumi and Yokosuka stations and at the Kanagawa substation.

The effects of power supplying conditions (supplied from one source or several sources interconnected), and the method of breaking the current of the leading train (breaking the current with or

Fig. 19.

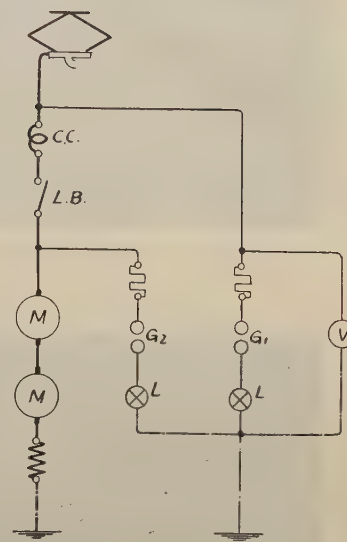


Fig. 20. — Connection diagram of gap-voltmeters.

M. Main motor.
C.C. Choke coil.
L.B. Line breaker.
G_1. Gap-voltmeter (gap 0.35mm.).
G_2. Gap-voltmeter (gap 0.30mm.).
L. Neon glow dis harge lamp.
V. Voltmeter.

without inserting resistance) upon the voltage rise were also recorded. The results of these tests are shown in tables 9 and 10.

As shown by these tables the maximum surge voltage induced when the current was cut off without inserting resistance is 3 040 volts, while that with inserting resistance is 2 280 volts. The maximum abnormal voltage rise occurs in the power line near the running train, and the rise is comparatively low near the substation.

Power supply from a single power source induces higher voltage rise than is the case when the power is supplied from several sources interconnected, i. e., surge voltage is low in the case of large back power.

Test results by gap-voltmeters are shown in table 11. As a rule, the discharging voltage of gap-voltmeters occurs chiefly at the trolley side of both trains, but sometimes the discharging voltage at the motor side rises above 1 850 volts in the test.

Figure 21 shows examples of oscillograms for the voltage rise due to cutting off of the current with or without inserting resistance. These were taken at three places at a pre-determined time.

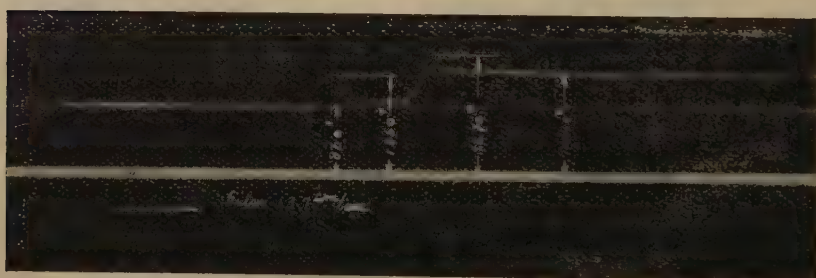
The principal elements that affect the abnormal voltage rise are here considered:

1. Line constants in power line and in locomotives.
2. Amount of current to be broken.
3. Breaking speed of current.

Fs-243 at Yokosuka station, 1 September 1926, at 3.11 a. m.

Fs-259 at Tsurumi station, 4 September 1926, at 1.10 a. m.

Fs-260 at Kanagawa substation, 4 September 1926, at 1.10 a. m.

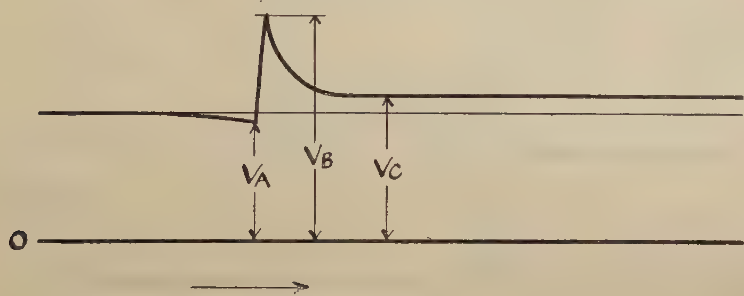


Fs-261 at Yokosuka station, 4 September 1926, at 1.10 a. m.

Fig. 21.

TABLE 9.

rge voltage induced when the current was cut off without inserting resistance
(Test results on 1 September 1926.)



Number oscillogram.	Oscillograph placed at	Photographed at	Surge voltage.			Position of leading train.	Break current.	Power supplied from
			VA.	VB.	VC.			
own train.	...	...	v.	v.	v.	...	Amp.	Oimachi sub-station Kanagawa sub-station and Ofuna sub-station, all in parallel.
Fs — 240	Yokosuka	1.30 a. m.	1 370	2 700	1 600	Zushi-Taura	1 200	
Up train.								Kanagawa sub-station.
Fs — 243	Yokosuka	3.11 —	1 030	3 040	1 620	Taura-Zushi	1 020	
Fs — 246	Y. kosuka	3.32 —	1 180	2 550	1 570	Ofuna-Totsuka	1 200	
Fs — 250	Tsurumi	4.22 —	1 280	2 160	1 570	Tsurumi-Kawasaki	1 140	

Sometimes the abnormal voltage reaches 2 000 to 3 000 volts in the power line and over 1 850 volts in the motor circuit in the tests described, but as the time duration of such high voltage is very short, we can imagine that such an instantaneous high voltage rise has no special effect upon the machinery of the electric locomotive or of the substation. The effect of the frequent application of surge voltage upon the machinery for a long run still remains unknown.

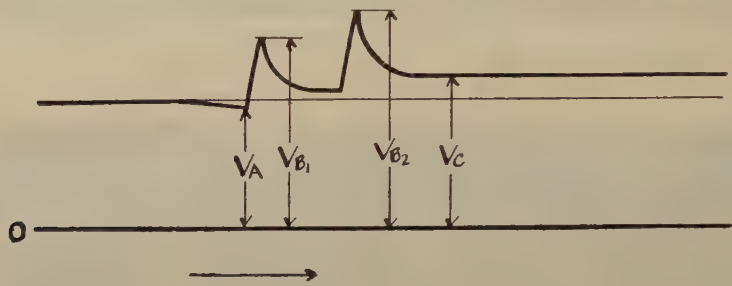
10. — SUMMARY.

General data on electrified railways and their locomotives were gathered from the

Table 10.

Surge voltage induced when the current was cut off with inserting resistanc

(**Test results on 4 September 1926.**)



Number of oscillogram.	Oscillograph placed at	Photographed at	Surge voltage. V_A.	V_{B_1}	V_{B_2}.	V_C.	Position of leading train.	Break current.	Power suppli from
			v.	v.	v.	v.			
Down train.									
Fs — 256	Tsurumi	0.12 a. m.	1 050	1 490	1 700	1 340	Kawasaki-Tsurumi	Amp. 1 140	Oimachi sub-stat
Fs — 257	Kanagawa	0.12 a. m.	1 000	1 385	1 540	1 270	Kawasaki-Tsurumi	1 140	Oimachi sub-stat
Fs — 258	Yokosuka	0.12 a. m.	910	1 060	1 200	1 075	Kawasaki-Tsurumi	1 140	Oimachi sub-stat
Fs — 259	Tsurumi	1.10 —	1 150	1 510	1 700	1 560	Totsuka-Ofuna	1 110	Oimachi sub-stat
Fs — 260	Kanagawa	1.10 —	860	1 360	1 670	1 440	Totsuka-Ofuna	1 110	Oimachi sub-stat
Fs — 261	Yokosuka	1.10 —	750	1 490	1 820	1 450	Totsuka-Ofuna	1 110	Oimachi sub-stat
Fs — 264	Yokosuka	1.30 —	190	1 800	1 950	1 440	Zushi-Taura	450	Oimachi sub-stat Ofuna sub-stati in parallel.
Up train.									
Fs — 267	Yokosuka	3.11 —	990	1 800	2 280	1 490	Taura-Zushi	1 170	Kanagawa sub-tion.
Fs — 270	Yokosuka	3.32 —	1 200	1 700	2 050	1 490	Ofuna-Totsuka	1 050	Kanagawa sub-tion.
Fs — 274	Tsurumi	4.22 —	1 300	1 780	1 940	1 515	Tsurumi-Kawasaki	1 050	Kanagawa sub-tion.

TABLE 11.

Performance of gap-voltmeter at predetermined time.

Date	Position of leading train	Gap-voltmeter: Leading train, Trolley side	Gap-voltmeter: Leading train, Motor side	Gap-voltmeter: following train, Trolley side	Leading train: Current, Amp.	Leading train: Speed, Km/hr	Power supplied from
1st Day (Sept. 1st)	Down train (break without inserting resistance)						
h–m–s a.m. 0–8–0	Kawasaki–Tsurumi	●	○	○	1,260	47	Oimachi substation, Kanagawa substation, Ōfuna substation, all in parallel
0–20–0	Kanagawa–Yokohama	○	○	○	1,170	57	
1–10–0	Totsuka–Ōfuna	○	○	○	1,230	45	
1–30–0	Zushi–Taura	●	○	●	1,260	—	
— " —	Up train (— " —)						
3–11–0	Taura–Zushi	●	○	●	1,020	—	Kanagawa substation
3–32–0	Ōfuna–Totsuka	●	○	●	1200	40	
4–12–0	Yokohama–Kanagawa	○	○	○	1,260	47	
4–22–0	Tsurumi–Kawasaki	○	○	○	1,140	45	
2nd Day (Sept. 4th)	Down train (break with inserting resistance)						
am 0–1–0	Shinagawa–Ōmori	○	○	○	1,350	50	Ōimachi substation
0–12–0	Kawasaki–Tsurumi	○	○	○	1,140	39	
1–10–0	Totsuka–Ōfuna	○	○	○	1,100	23	
1–30–0	Zushi–Taura	○	○	○	450	39	Ōimachi substation, Ōfuna substation in parallel
— " —	Up train (— " —)						
3–11–0	Taura–Zushi	●	○	●	1,170	30	Kanagawa substation
3–32–0	Ōfuna–Totsuka	○	○	○	1,050	40	
4–12–0	Yokohama–Kanagawa	○	○	○	1,140	52·5	
4–22–0	Tsurumi–Kawasaki	○	○	○	1,050	47	

Remarks : ● Discharge. — ○ No discharge.

Discharge voltage :

Leading train, trolley side . . . . . 2150 volts.
——————, motor side . . . . . 1850 —
Following train, trolley side . . . . 1900 —

British Empire, China and Japan. The electrified sections are not as yet very extensive. Usually the system of electrification is the d. c., the voltages being different. The locomotives are mostly of the nose-suspension single gear type. The Japanese Government Railways with many of this type have found that this type is quite satisfactory so far as the locomotive itself is concerned. Its effect upon the maintenance of the track is different, depending upon whether or not the locomotive is equipped with a well designed leading truck. From the results of the tests which have been carried out by using stremmatographs and deflectionmeters, we conclude that generally the nose-suspension type with a leading truck attacks the track less than a steam locomotive, while the attack of the locomotive without a leading truck is greater. That the amount of flange wear of the driving wheel tire of the former is less than that of the latter is another evidence that a good leading truck is an important factor, even for locomotives of medium speed as well as those for high speed services. The simple and solid construction of this type is also preferable, and it affords ample room for its equipments. Thus the nose-suspension type with a leading truck is regarded as a desired one for d. c. locomotives.

An individual axle drive type of a proper design is also a good type. But in this type it is rather difficult to arrange the machinery and apparatus in such a way as to be quite convenient for inspection, in the case of the employment of the high tension d. c. system. In the case of d. c. locomotives, it is convenient to arrange corridors on both sides of the body if the floor space permits. The high tension equipments are located in the central part and a small central passage through the high tension and rheostat compartments should be provided, if possible. This arrangement makes all apparatus accessible and inspectable.

As to control equipments three points were discussed, the first being the safety device for the main circuit. According to our experience a fuse or an ordinary circuit breaker is not reliable as a sufficient safety device. There is no better way than to equip a high-speed circuit breaker on each locomotive when the high tension d. c. system is used. The second is the type of the contactor. The unit switch control seems to be most extensively used on d. c. locomotives. It is practical, but we are of opinion that the combination of the cam shaft control and unit switch control is preferable, the former being applied to combination switches of the main motors, whose sequence of action must be quite exact. The third is the manner of cutting off the main circuit. In some of our locomotives, the main circuit is cut off without inserting resistance.

This induces high surge voltage and, therefore, we prefer to cut off the main circuit by inserting resistance.

It is desirable to obtain constant voltage current for the control circuit, especially if a high-speed circuit breaker is used. Seven types of motor-generator sets for this purpose are briefly described. The motor-generator set having an exciter for the motor mounted on the same shaft is preferable for railway service, when good voltage regulation and solid construction are considered.

We had much trouble with traction motors, though much of this trouble has now been eliminated. Inferior insulating material was one of the causes. Frequent heavy rains and dense humidity in Japan may have considerable effect upon

the insulating properties of the materials used. The flash-over of the commutator occurred several times. Vibration of brushes due to severe vibration of the truck seems to be the essential cause. According to test results, the surge voltage sometimes reaches 2 000 to 3 000 volts in the power line and over 1 850 volts in the motor circuit. The duration is short so that no special effect upon the machinery is foreseen. But its effect for a long period still remains unknown.

[621 .335]

REPORT No. 1

(France and Colonies)

ON THE QUESTION OF ELECTRIC LOCOMOTIVES FOR MAIN LINE TRACTION (SUBJECT VII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By Mr. DE BOYSSON,

CHIEF MECHANICAL ENGINEER, PARIS-ORLEANS RAILWAY COMPANY,

and

Mr. LEBOUCHER,

CHIEF ENGINEER, ROLLING STOCK AND LOCOMOTIVE RUNNING DEPARTMENT, MIDI RAILWAY COMPANY.

Figs. 1 to 24, pp. 1735 to 1756

The classification of locomotives into three groups :

— passenger,

— goods,

— mountain,

does not correspond to the types used by the railway companies of France and her Colonies. There is no special type in use on the mountain lines and the same type is used for goods and passenger working up to a speed of 80 km. (50 miles), a type derived from the tramway pattern with the motors supported by the nose. Only in the case of express trains with their greater speeds has it been necessary to consider the use of special types.

Under such conditions we thought it better not to follow the projected classification in our report, and we have simply classified the locomotives according to the method of suspension of the motor.

All the main line electric locomotives actually in service in France and in the French colonies use 1 500-volt continuous current with the exception of the railways of Morocco where continuous current at 3 000 volts is employed, and the suburban locomotives and motor coaches of the State Railways which although intended to work eventually at 1 500 volts are usually fed with continuous current at 750 volts, as are also several of the locomotives of the Midi Railway Company on the Perpignan to Villefranche line which were designed for monophase current at 12 000 volts, 16 2/3 periods per second, as an experiment before the war.

New and interesting designs have been successfully carried out on the electric locomotives of the French railways, both from the mechanical and electrical points of view. We will examine these in turn and terminate the report by giving a summary of the operating results.

(1) This question runs as follows : « *Electric locomotives for main line traction* : *a*) passenger locomotives; *b*) goods locomotives; *c*) locomotives for mountainous country. Multiple unit traction. »

(2) Translated from the French.

I. — MECHANICAL DETAILS OF THE LOCOMOTIVE.

The mechanical qualities to be looked for in an electric locomotive are first of all the proper suspension of the motors and then of the body which contains the gear and carries the staff, that is to say its steadiness in running.

The suspension of the motors makes it possible to divide the locomotives into three classes :

— the first is that in which the motors are not spring borne at all;

— the second when they are partly sprung or when the nose is carried on springs;

— the third when they are fully sprung or carried in the body.

Class I.

This class is represented in France and her Colonies by a single locomotive known as « Gearless » (fig. 1.) built by the General Electric Company for the Paris-Orleans Railway. The armatures of the six motors are keyed on the axles themselve while the carcases are carried on the frame. The armatures of the motors are therefore obviously exposed to very violent shocks without any cushioning when travelling at high speed or on bad track. But if they are built in such a way as to be able to stand such shocks the solution is a good one because it results in very great simplicity. This type of locomotive has often been criticised for its destructive action on the track because of the low centre of gravity and the increase in the unsprung weight.

In reality the unsprung weight is rather less than that of electric locomotives with motors with the nose spring carried and also with rod drives. As to the lowering of the centre of gravity, it would seem that its harmful action on the track has been exaggerated when this is in good condition; actually on the Paris-Orleans Railway no damage to the track caused by the running of this engine has been observed and it would seem that the « Gearless » locomotive would have been satisfactory in service if its mechanical part, now being rebuilt, had been as well designed as the electrical side.

Class II.

Locomotives having motors with the nose spring carried.

This type of locomotive includes nearly all the goods and passenger locomotives of the Railway Companies of France and Morocco with the exception of those intended for trains at a speed exceeding 90 km. (55.9 miles) per hour which latter all belong to the third class except one experimental locomotive on the Paris-Lyons & Mediterranean.

The easy riding and bearing of a motor with the nose spring carried on a normally maintained track is excellent up to a speed of 75 km. (46.6 miles) per hour. The experience of the Midi and Paris-Orleans Railway Companies goes to show that it is possible to attain, with well designed machines, 90 km. (55.9 miles) per hour and over, but these speeds on cheaply maintained lines can lead to rapidly increasing maintenance expenses and in fact it is better not to exceed a speed of 80 km. (50 miles) per hour with this type of locomotive except on very good tracks and with specially designed engines.

Having arrived at this conclusion let us examine the different types in service.

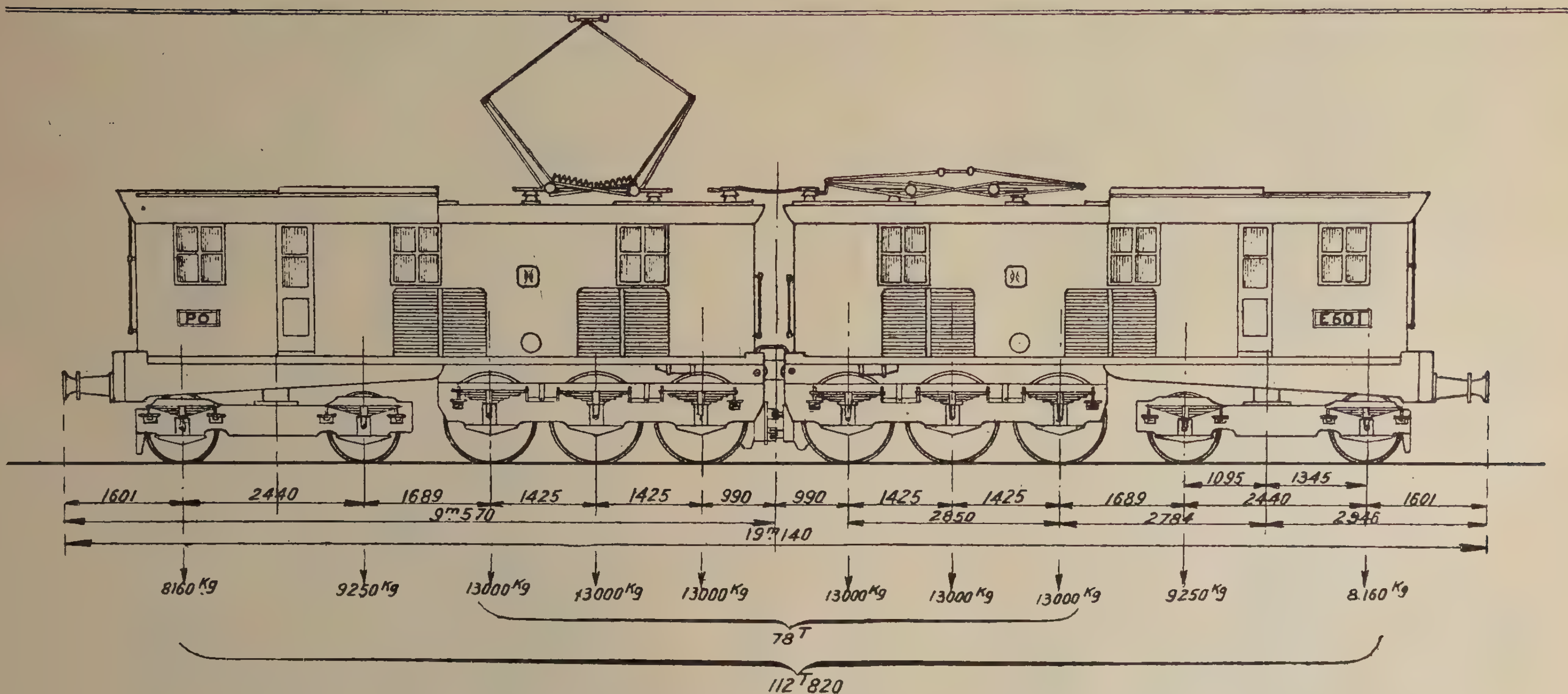


Fig. 1. — Gearless type high-speed trial locomotive of the 2 CC 2 type, No. E601, for the Paris-Orleans Railway.

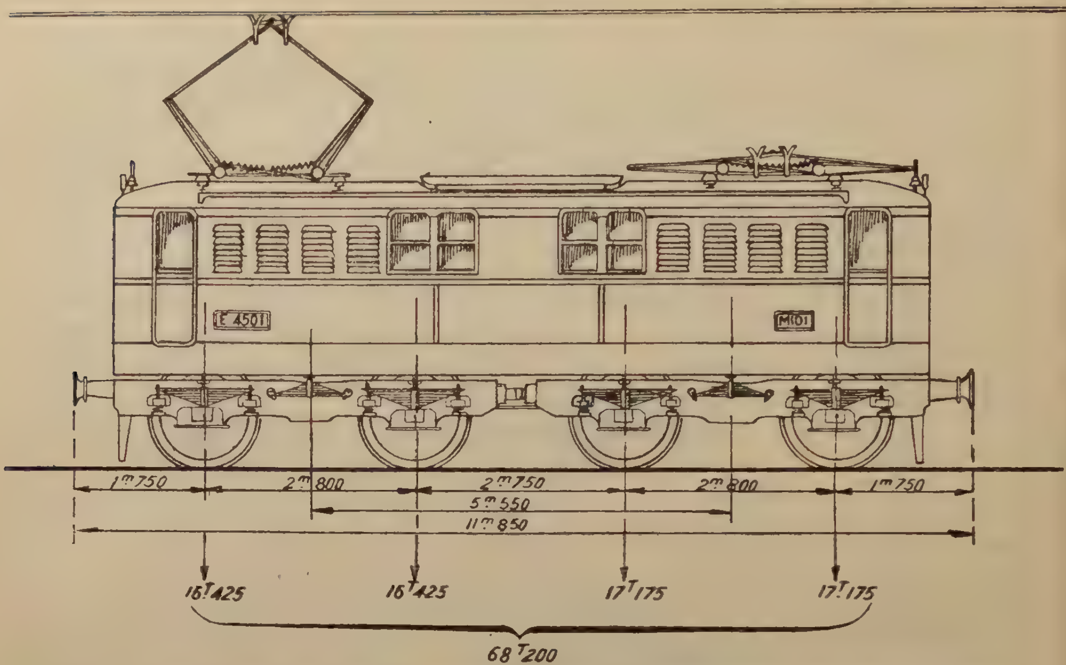


Fig. 2. — Electric locomotive, type BB, class 4501, built by the « Constructions Electriques de France » for the Midi Railway.

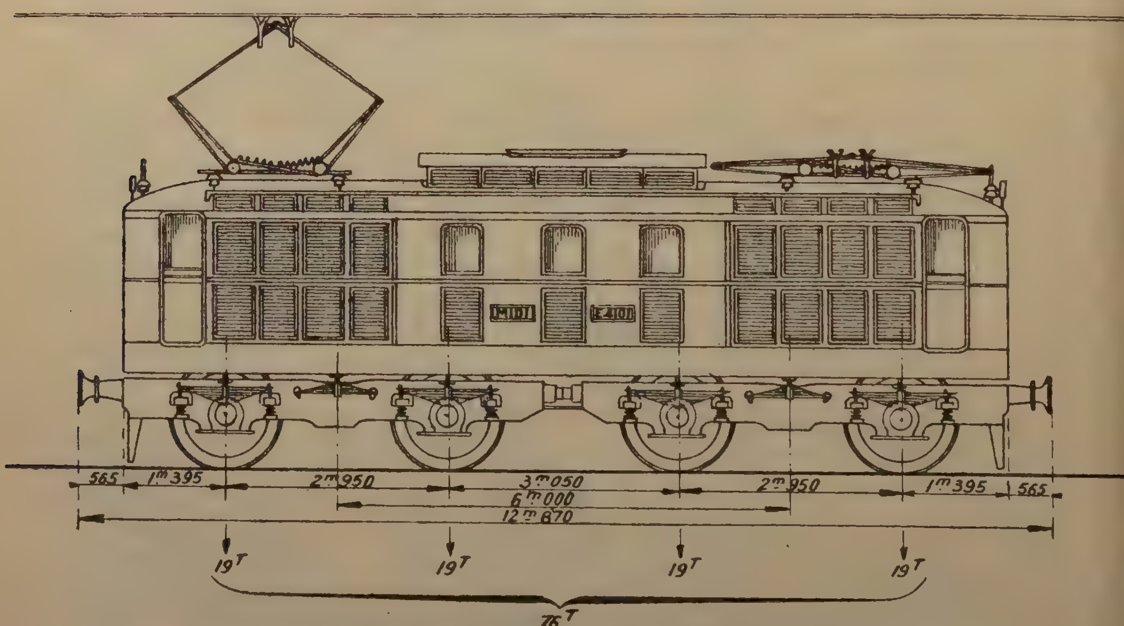


Fig. 3. — Electric locomotive, type BB, class 4101, built by the « Constructions Electriques de France » for the Midi Railway.

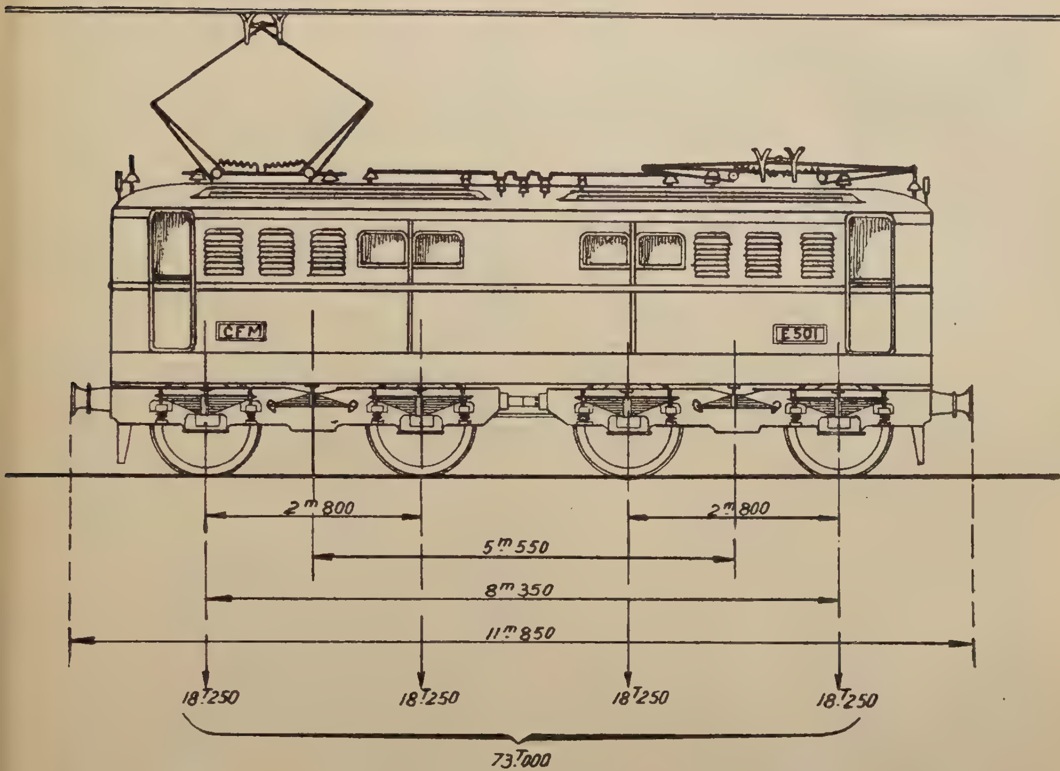


Fig. 4. — Electric locomotive, type BB, class E 501, built by the « Constructions Electriques de France » for the Morocco Railways.

Locomotive BB, Constructions Electriques de France type (Midi Railway, figs. 2 and 3.—*Paris-Orleans—Morocco,*fig.4).

The most common is the type designed by the Constructions Electriques de France, at Tarbes. It consists of 230 locomotives on the Midi Railway, 16 on the Paris-Orleans, 10 on the Paris, Lyons & Mediterranean, and 26 in Morocco.

As this design was not mentioned in the last report by Mr. Weiss, and as it has not been very well described in several recent technical publications, we propose to give rather fuller details of its chief characteristics.

The bogies are coupled together by means of a spring coupling in order to check nosing and are fitted with the necessary buffer and draw gear. The body therefore is used only to hold the control gear and carry the staff. In order to give the couplings ample play without straining the body, one of the pivots is given longitudinal play. The construction of the bogies is very simple; it consists of a rectangular frame and a cast steel bolster on which the body rests through a convex spherical pivot carried low down and to which the two motors are attached through springs.

The bogies have a single set of springs.

The flexibility is only 1.5 mm. (0.059 inch) per ton for the locomotive as a whole.

The body being carried on two spherical convex pivots, one on each bogie, is able to rock several degrees to each side by turning round an imaginary longitudinal axis O which is very low down (beneath the axles).

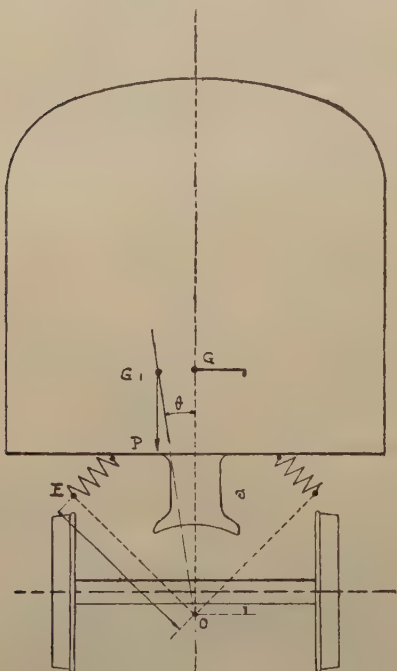


Fig. 5.

The body is normally held in the vertical position by means of plate springs called balancers which, in order to hold the body in position have only to overcome the effect of gravity when the body gets out of the vertical. For a slope of θ the turning movement of the body about O is $Pad\theta$.

(a = OG the distance of the axis of oscillation from the centre of gravity G of the body. fig. 5.)

To restabilise the body it is only necessary to employ a spring of rigidity K, $\left(K = \frac{1}{\varphi}\right)$ working at a distance r from O and of which the couple will be $Kr^2d\theta$. If several springs are used the straightening couple will be $\Sigma Kr^2d\theta = Pad\theta$.

The period of the oscillation of the body is as much longer as the restraining couple is weaker, and it is thus possible to obtain a very steady vehicle. Part of the weight of the body (20 to 30 %) can be supported by the balancers if they are so arranged on each side of the body that they deflect on a line at right angles to a vector radius OE slightly inclned on the horizontal.

In fact, this locomotive has two independent sets of springing, a vertical suspension which absorbs the vertical shocks of the track by means of the primary springs of the bogie, and a lateral suspension which absorbs the lateral shocks due to the nosing of the bogies and when entering curves by means of balancers.

These locomotives run very steadily. On the Paris-Orleans they have been driven up to 110 km. (68.3 miles) per hour. On the Midi the heating up of the motors has prevented such speeds being attained.

On the whole of the locomotives of the Midi and on the new locomotives for Morocco, the motors transmit their power to the axle by means of two absolutely symmetrical gear wheels; the rim of the gear wheels is divided into two parts secured to the wheel centre by dowels so that the axle is not subjected to torsion and the armature bearings, as every thing is symetrical, carry the same loads. There is no elastic member in either gears or wheels. It can be said straight away that this method of assembly has given entire satisfaction.

Locomotive BB of the Paris-Orleans.

Of the 200 locomotives BB in service on the Paris-Orleans Railway 16 are of the « Constructions Electriques de France » (C. E. F.) type.

The remaining 184 have many points in common.

The body carries the buffing and draw gear; the motors of a continuous rating of about 350 H.P. transmit their power to the wheels by means of a single pair of gears. The singlepiece gear wheel is keyed to the axle itself; this simple solution makes it necessary to remove a wheel when a gear has to be changed.

These locomotives differ most of all in the bogies.

The 80 locomotives supplied by the « Société d'Etudes pour l'Electrification des Chemins de fer » have two direct spring bogies with equalisers (fig. 6).

The very large plain pivot is hollow and serves as a ventilating shaft for the traction motors. The total deflection of the locomotive springs is 2.5 mm. (0.098 inch) per ton.

The 80 locomotives supplied by the « Groupement Société des Batignolles-Société Oerlikon » have two bogies (fig. 7) with bolsters and therefore double sets of springs which give a total deflection of 2 mm. 8 (0.11 inch) per ton.

The 24 locomotives supplied by the « Société Alsacienne » have the same kind of bogies as the preceding type and the same flexibility (fig. 8).

These 3 types of locomotives can be driven in the normal way up to speeds of 90 km. (55.8 miles) per hour without inconvenience; however the Batignolles-Oerlikon type which has proved to be the most stable is given preference on workings requiring these speeds. Certain machines with suitable gear ratios attain in ordinary working 105 km. (65.2 miles). The stability on the road of these latter locomotives however will be somewhat less than that of the C. E. F. type with side equalisers.

Locomotives of the Paris, Lyons & Mediterranean.

The Paris, Lyons & Mediterranean has ordered three sets of ten locomotives of the I CC I type with motors having spring borne noses, from three different designs, and has tried to get different solutions for both the arrangement of the gear wheels and the transmission of the driving force, so as to be in position to make some useful comparisons.

For this reason, on the locomotives designed by the « Compagnie Electro-Mécanique et Fives-Lille » (I CC I from 1 to 10), the locomotive is formed of two bodies coupled together (fig. 9) each body having three driving axles and a pony truck; the motors transmit their power to the wheels by means of two non-elastic gears, the toothed wheel being fastened to the wheel centre as in the BB locomotives of the Midi Company. One of the locomotives has been provided with flexible gears.

The locomotives designed by the « Constructions Electriques de France » and the « Société Alsacienne » (I CC I from 1 to 10) consist of a single body (fig. 10) resting on two bogies with three driving axles and one pony truck, by means of inverted pivots and equalisers (Midi type). There are also two trains of gears per motor but the toothed wheels are keyed directly to the axle and include a flexible member.

The locomotives designed by the « Société d'Etudes » consist of two bodies coupled together (fig. 11). Each body carries two ordinary driving axles and

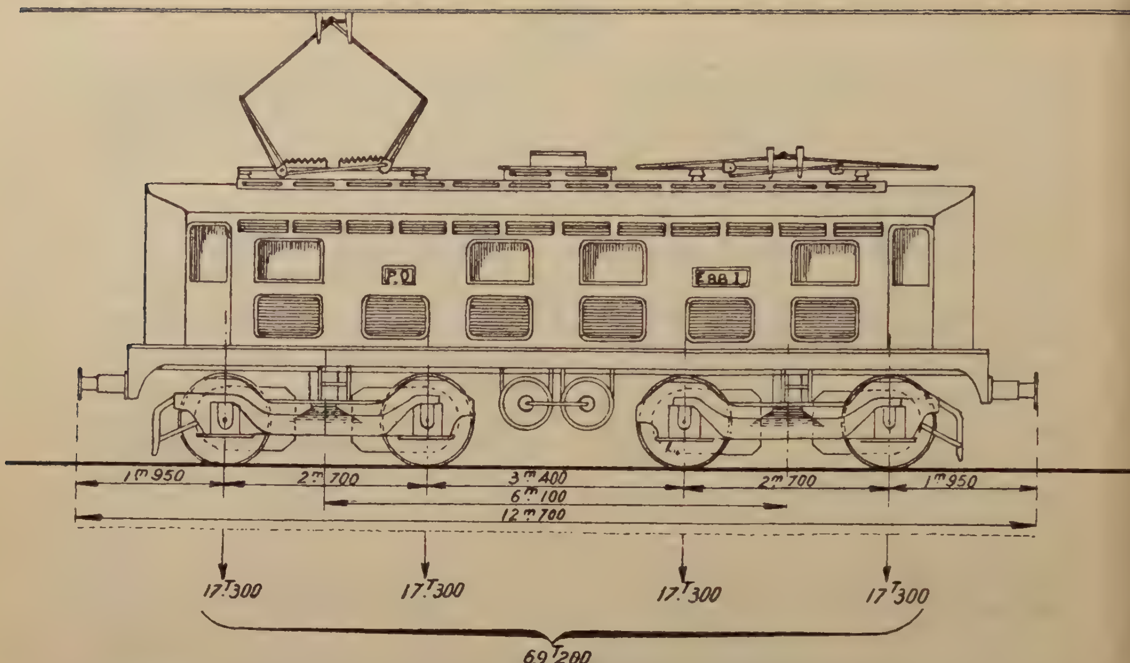


Fig. 6. — Electric locomotive, type BB, class E BB 1, built by the « Société d'Etudes pour l'Electrification des Chemins de fer Français » (Thomson-Houston, Schneider et Jeumont) and Electro-Mécanique, for the Paris-Orleans Railway.

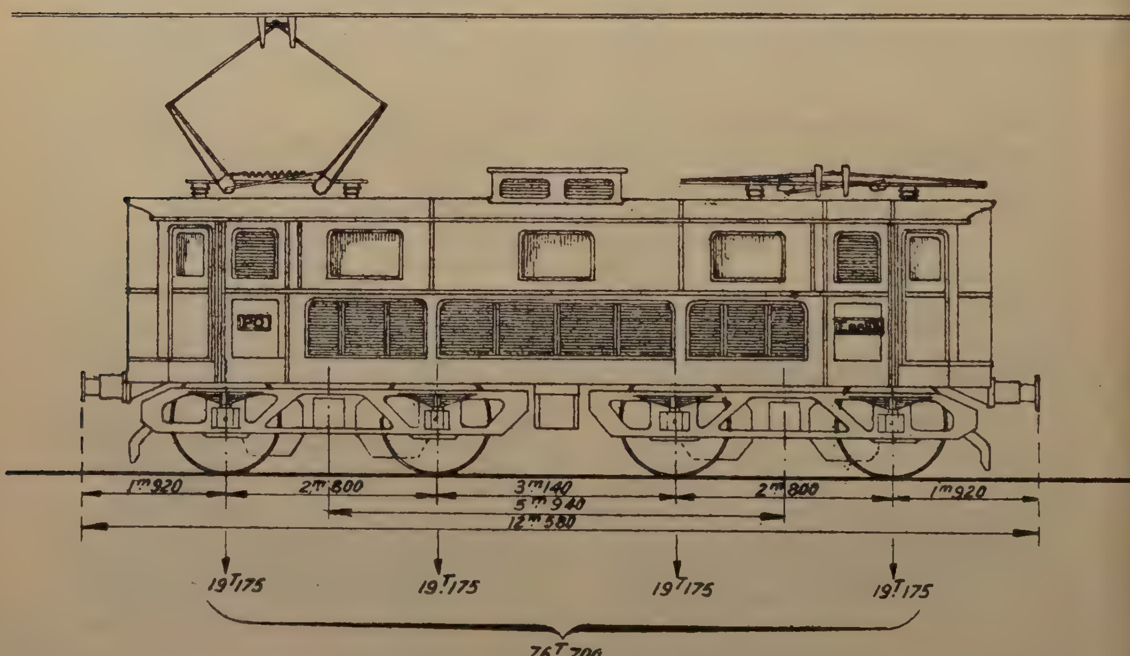


Fig. 7. — Electric locomotive, type BB, class E 101 to 180, built by the « Société des Batignolles et Oerlikon » for the Paris-Orleans Railway.

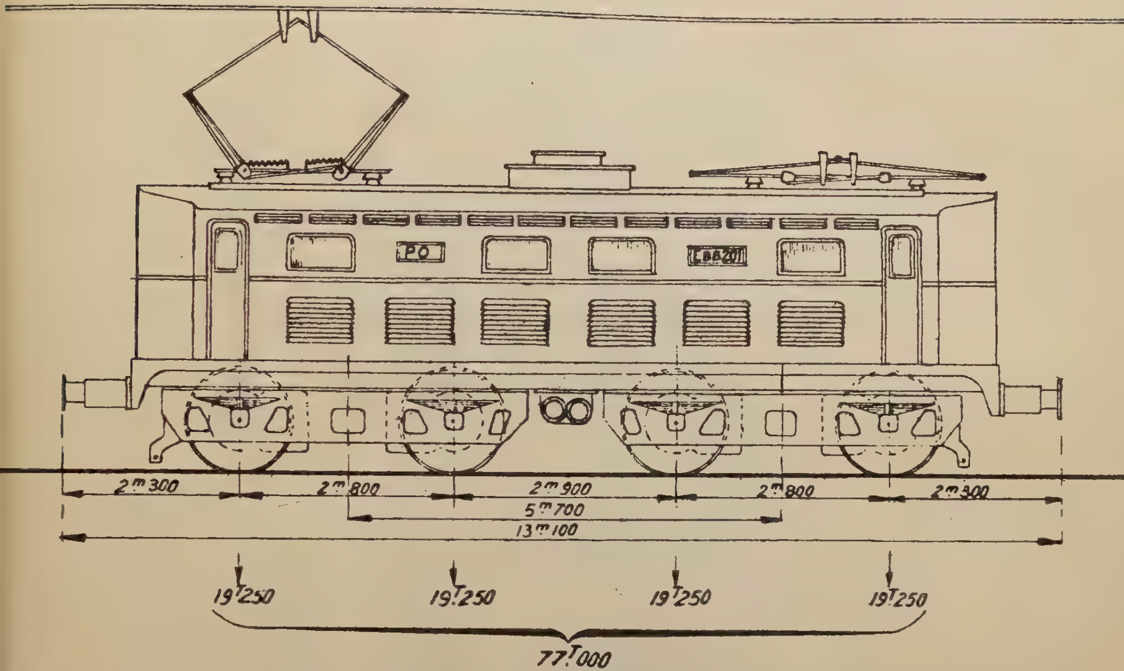


Fig. 8. — Electric locomotive, type BB, class E 201 to 224, built by the « Société Alsacienne de Constructions Mécaniques » for the Paris-Orleans Railway.

rests on a bogie having a driving axle and a carrying axle. The toothed wheels are keyed to the axle and there is only one train of gears.

Finally the « Société d'Etudes » has designed a locomotive of the same type as the preceding ones but which can run up to 110 km. (68.3 miles) per hour. (I CC I AE I). The motors have only a single train of gears, the spur wheel is keyed on the axle but the gear wheel driving it is flexible.

Locomotives of the State Railways (fig. 12).

The State Railways possess 30 locomotives of the BB type with bogies of the P. O. type of the « Société d'Etudes »; *i. e.* with simple suspension and equaliser levers. Each motor has a continuous rating of 140 H. P. These suburban locomotives work on continuous current at 750 volts.

Locomotives with motors in the bodies.

This construction which is very costly has only been adopted for very high speed locomotives. Obviously it results in the motors working under the best conditions. The chief question then was the way the locomotive would behave when out on the line, *i. e.* its stability.

We have already said that the steadiness of the body depended on its own period of oscillation on its springs. The longer the period the better it is.

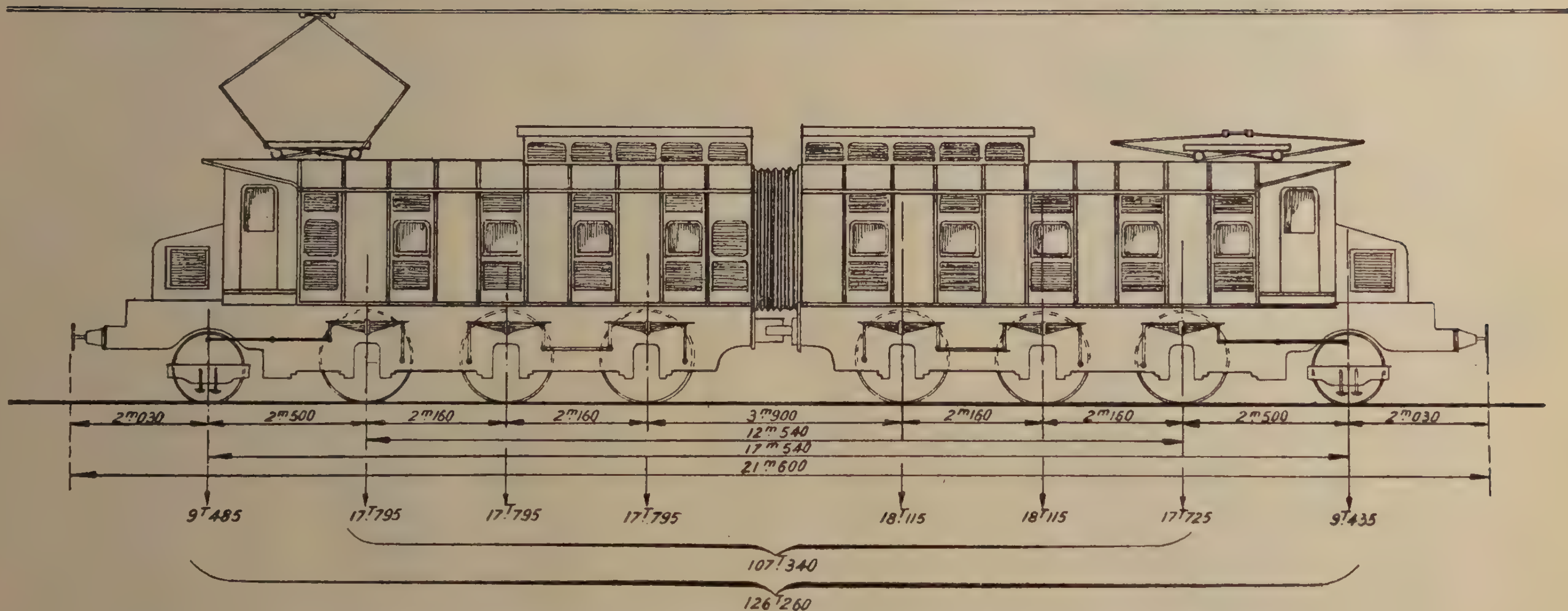


Fig. 9. — Electric locomotive, type 1 CC 1, class DE 1 to 10, built by the « Electro-Mécanique and Fives-Lille » Companies for the Paris, Lyons & Mediterranean Railway.

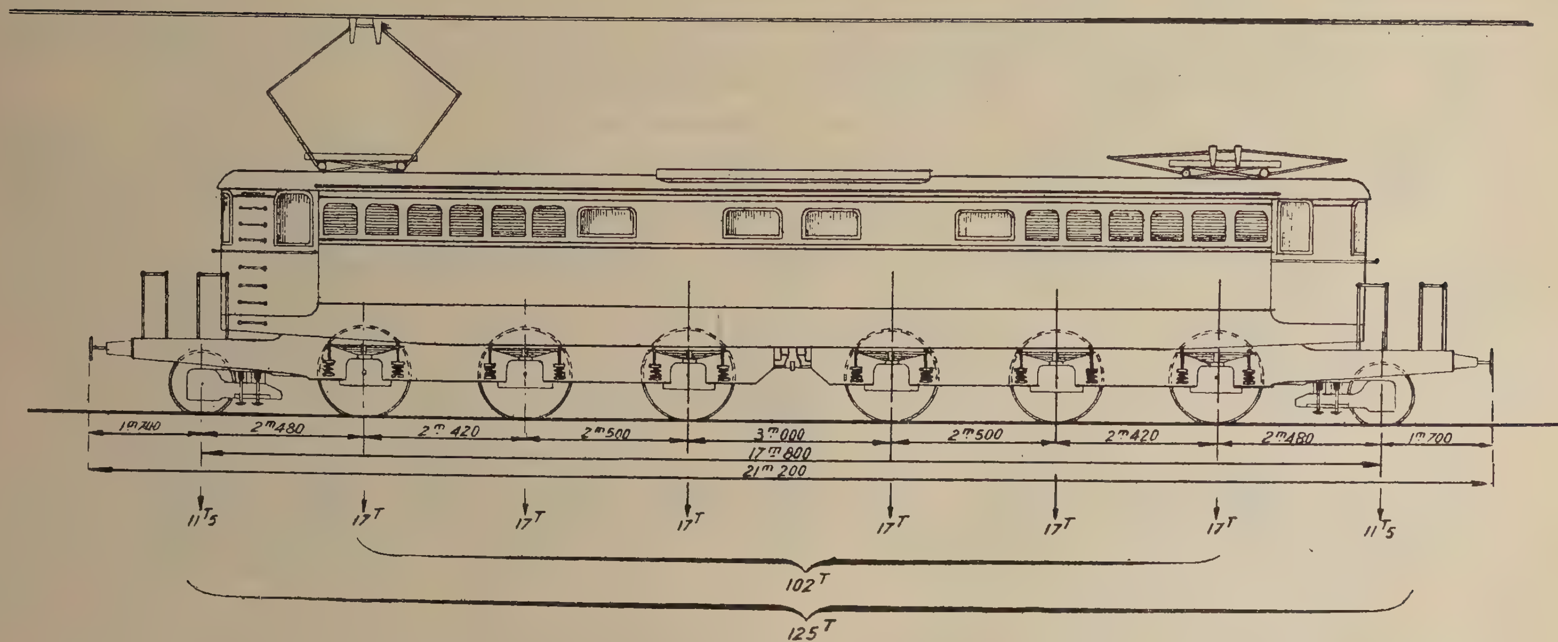


Fig. 10. — Electric locomotive, type 1 CC 1, class C. E. 1 to 10, built by the « Constructions Electriques de France » and the « Société Alsacienne » for the Paris, Lyons & Mediterranean.

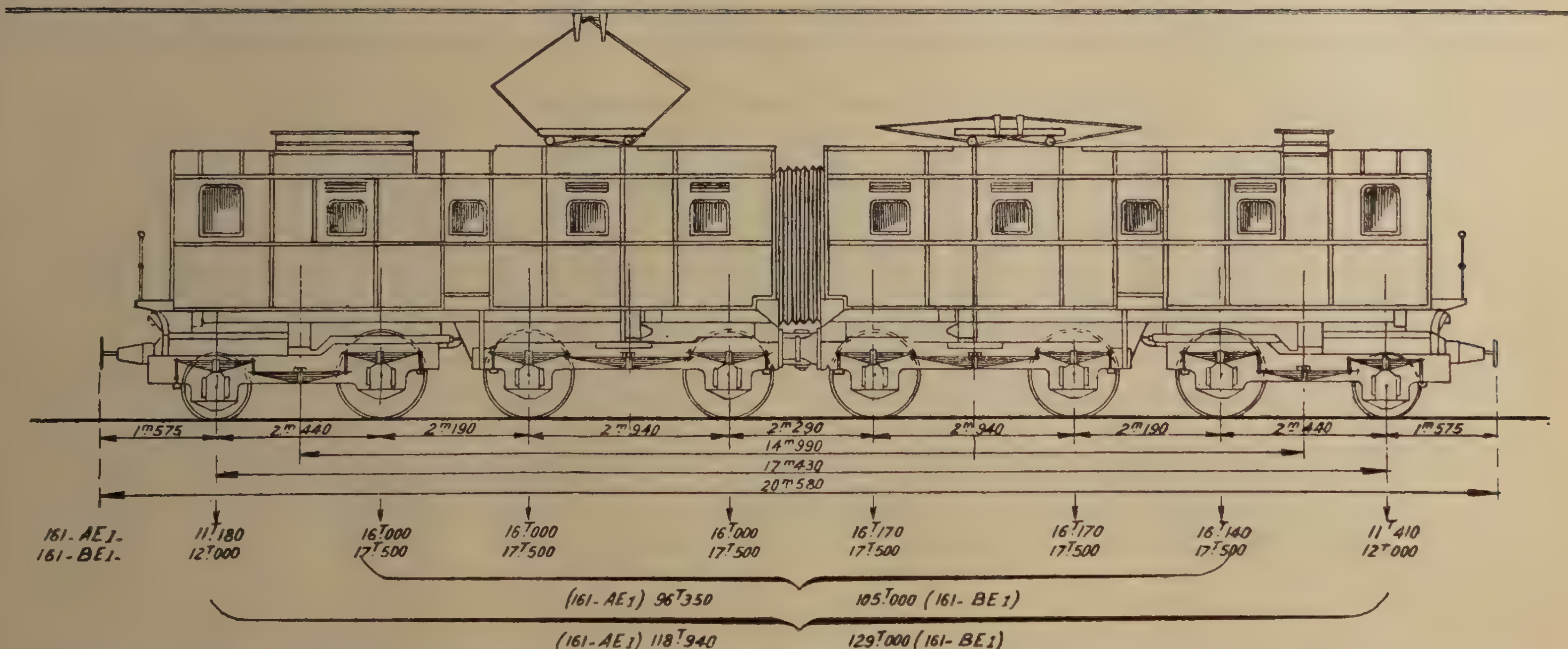


Fig. 11. — Electric locomotive of high speed type 1 CC 1-AE 1 and BE 1, built by the « Société d'Etudes pour l'Electrification des Chemins de fer Français » (Thomson-Houston, Schneider and Jeumont) for the Paris, Lyons & Mediterranean Railway.

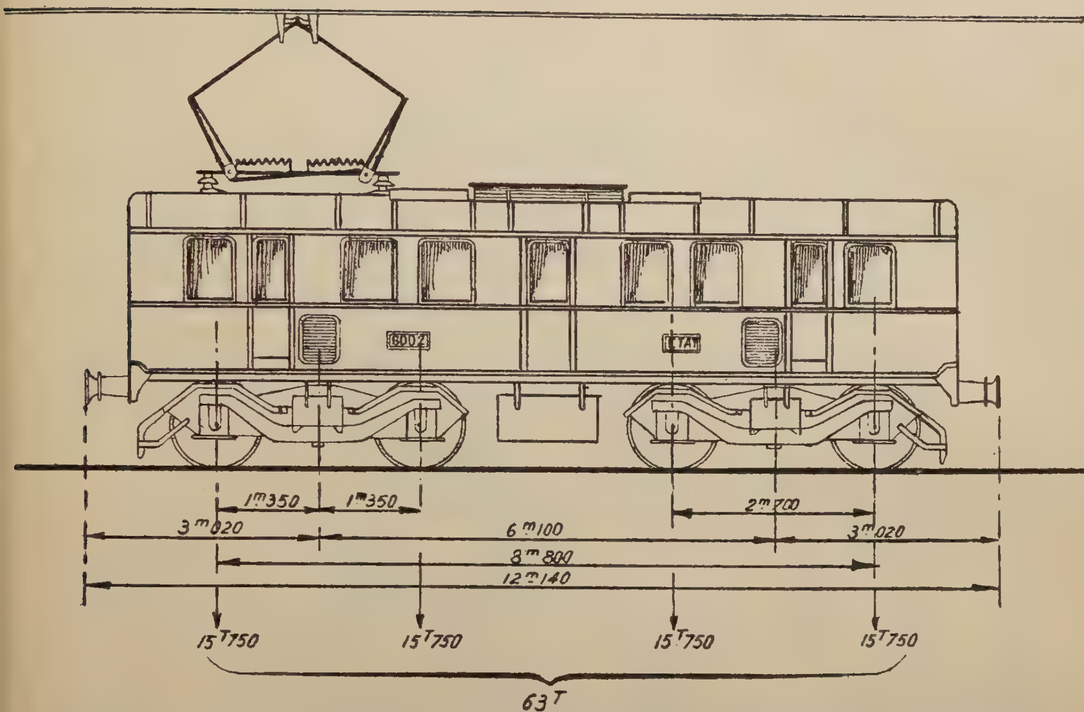


Fig. 12. — Electric locomotive, type BB, built by the « Société d'Etudes pour l'Electrification des Chemins de fer Français » (Thomson-Houston, Schneider and Jeumont) for the French State Railways.

The sprung part of the locomotive can be compared to a compound pendulum of which the axis of oscillation is the intersection of the longitudinal plane of the machine with the plane through the spring hangers on the frame. Under these conditions the value of the period of oscillation will be found to be :

$$T = 2\pi\sqrt{\frac{I}{2Kr^2 - Pa}}$$

in which I is the moment of inertia of the body about the axis of oscillation determined as above; K the rigidity of the springs or the reciprocal of their flexibility; r the half the distance between the springs; P the weight of the body; a the distance of the centre of gravity of the spring borne part to the axis of oscillation (fig. 13); if CD be the vertical carrying the resultant of the action of the springs R' and R'' for an inclination θ of the body, this straight line cuts at a point M the straight line GO joining the centre of gravity to the axis of oscillation.

Let $\rho = OM$.

In taking the moments of the forces applied to the springs as regards point O we have :

$$\cos\theta \sin\theta \Sigma 2Kr^2 = P\rho \sin\theta$$

θ being small, $\cos\theta$ can be taken as equal to 1, we obtain :

$$\Sigma 2Kr^2 = P\rho$$

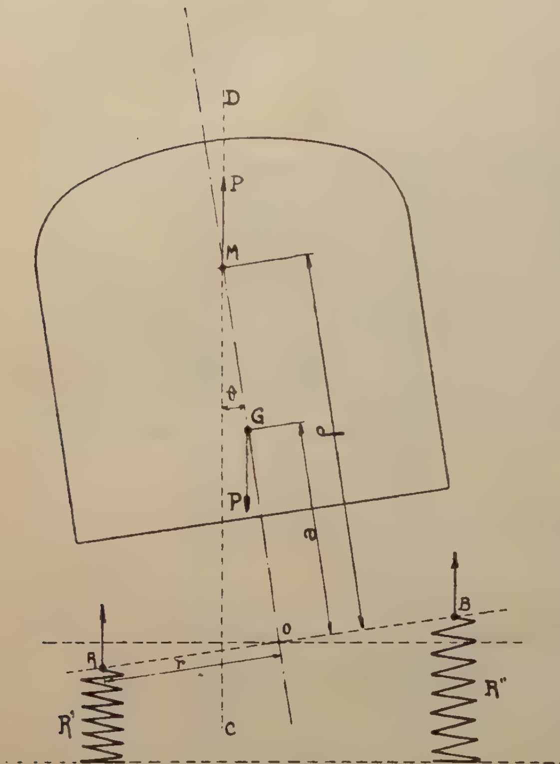


Fig. 13.

and the formula giving the period of oscillation becomes

$$T = 2\pi \sqrt{\frac{I}{P(\rho - a)}}$$

This formula is absolutely indentical to the formula for the stability of ships. ρ is the height of the metacentre M.

From this it will be seen that to get a long period of oscillation, $(\rho - a)$ must be as small as possible, what may be obtained either by increasing a, that is to say by raising the centre of gravity, or by decreasing ρ that is to say by lowering the metacentre, or even by altering both at once.

We will now examine the solutions adopted by the different Administrations.

The first difficulty encountered in the construction of very high speed locomotives has been the presence of the main frame plates, which on account of their nearness together, made it impossible to have sufficiently powerful horizontal motors. All the builders had suggested placing the motors above the frame, either retaining the horizontal axis or by adopting vertical motors. But all these solutions gave birth to a new problem, that of the transmission of the driving forces to the axles.

Ganz locomotives of the Paris-Orleans.

The locomotives E 401 and E 402 of the Paris-Orleans (fig. 14) have been built by the Ganz Company at Budapest. They are of the 2D2 type and consist of two leading bogies and four driving axles fitted with axleboxes guited in the main frame of the locomotive. The body carries four horizontal motors each of about 1 100 H. P. at the one hour rate. Each group of two outer motors transmits its power to the outer driving axle by means of the Kando system of knuckle-jointed connecting rods. The second driving axle is coupled to the leading axle by two ordinary coupling rods.

The Kando system of connecting rods is so designed that they can yield a little under the effect of the horizontal vertical movements applied to the main crank pin, but will not give at all under the effect of the horizontal stresses applied to this pin. From the point of view of the mechanical results it is nothing else than an ordinary triangular connecting rod with a vertical guide. But as it should follow all the movements of the axle it must be able to oscillate round the axis passing through the two crank pins of the

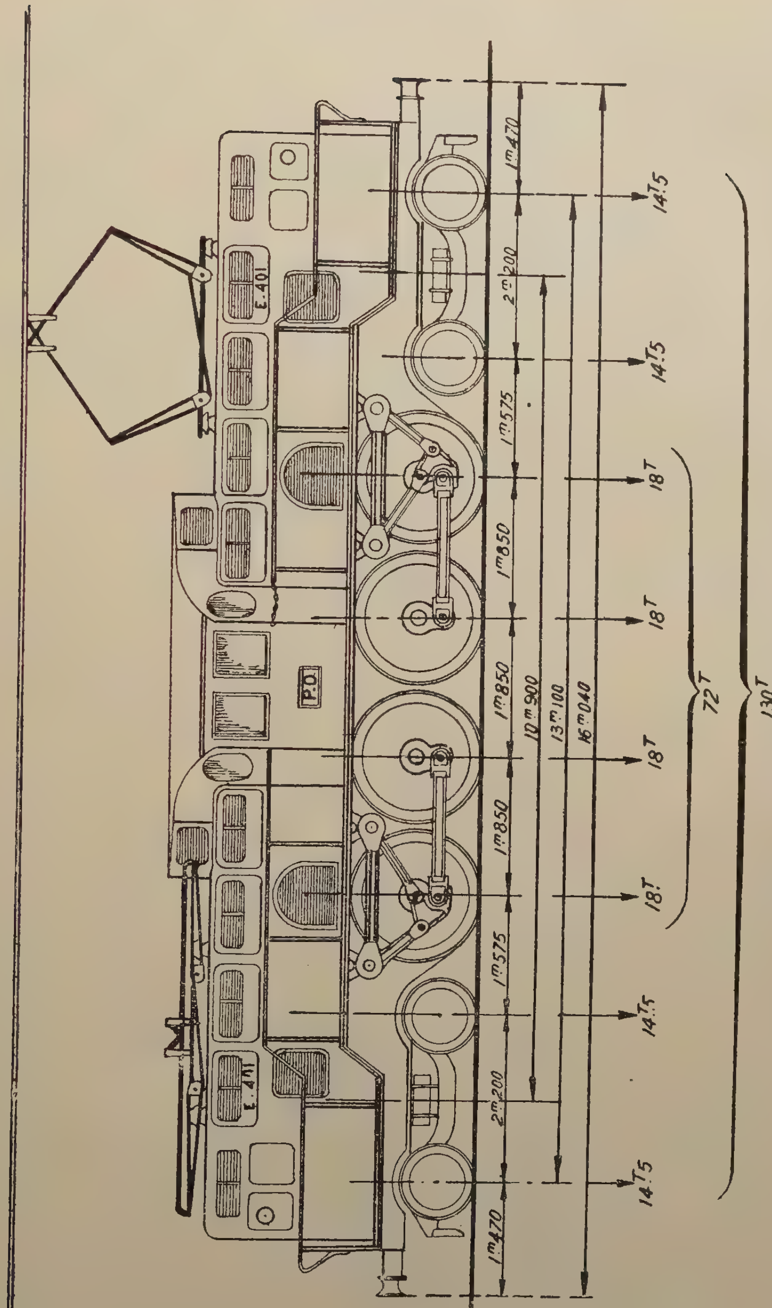


Fig. 14. — High-speed electric locomotive type 2 D 2-E 401 built by the " Ganz Company " for the Paris-Orleans Railway.

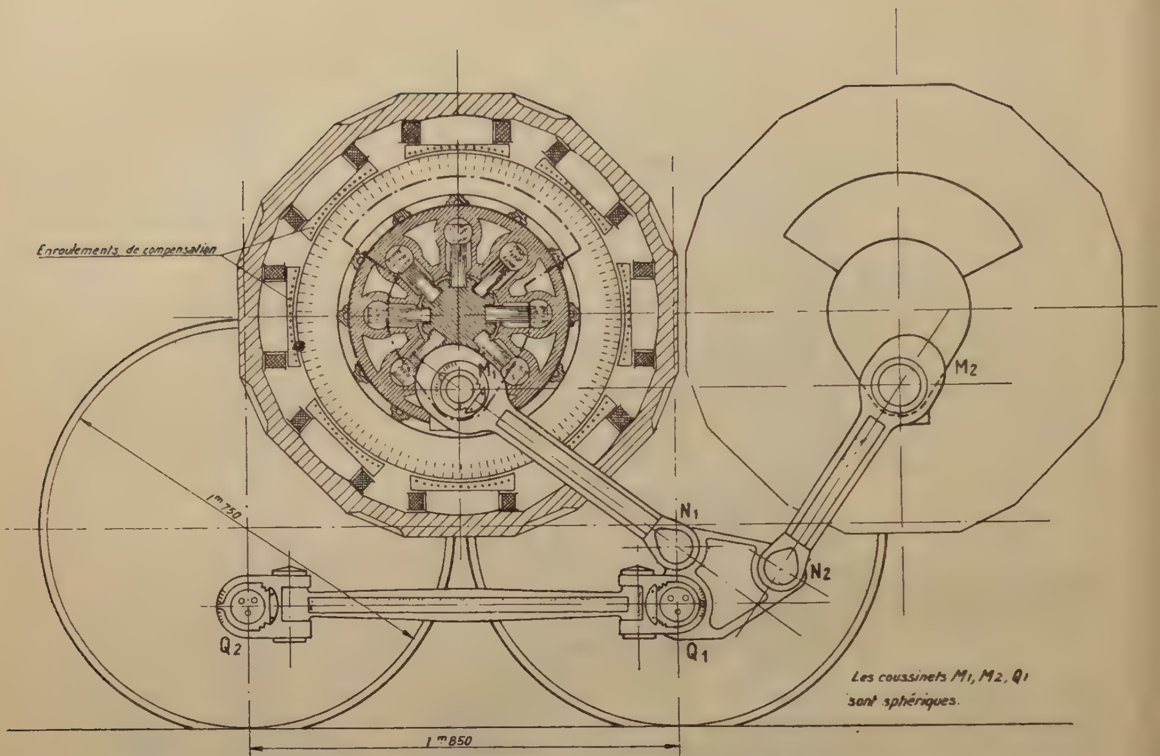


Fig. 15. — Isostatic driving gear of the electric locomotive type 2 D 2, E 402 buit by the « Ganz Company » for the Paris-Orleans Railway.

Explanation of French terms : Enroulements etc. = Compensatory windings. — Les coussinets etc. = The bearings M1, M2, Q1 are spher

motors and must have three spherical joints. The locomotive 402 has an isostatic system of rods (fig. 15); locomotive 401 is connected hyperstatically (the crank pins are joined by two coupling rods).

Brown-Boveri locomotive of the Paris-Orleans (fig. 16).

The design adopted on the 2D2 501 and 502 locomotives of the Paris-Orleans built by Brown-Boveri consists in driving each axle by a special motor of an hourly rating of 900 H. P. placed just above the axle, the shaft of which passes above the wheel and transmits its power by means of two symmetrical pinion wheels to two overhanging spur wheels attached to a bracket fastened to the main frames and placed in face of, but outside the outer edge of the driving wheels. In this way the motor is overhead, the springs are inside, therefore two conditions favorable to stability when on the road are realised because the centre of gravity is raised and the metacentre lowered. We are brought back to the classical but difficult problem of how to transmit the movement of a wheel forming part of the frame to an axle which moves vertically $\pm$ 4 cm. (1 9/16 inch), sideways $\pm$ 3 cm. (1 3/16 inch) and which can take a slope of the order of 10°.

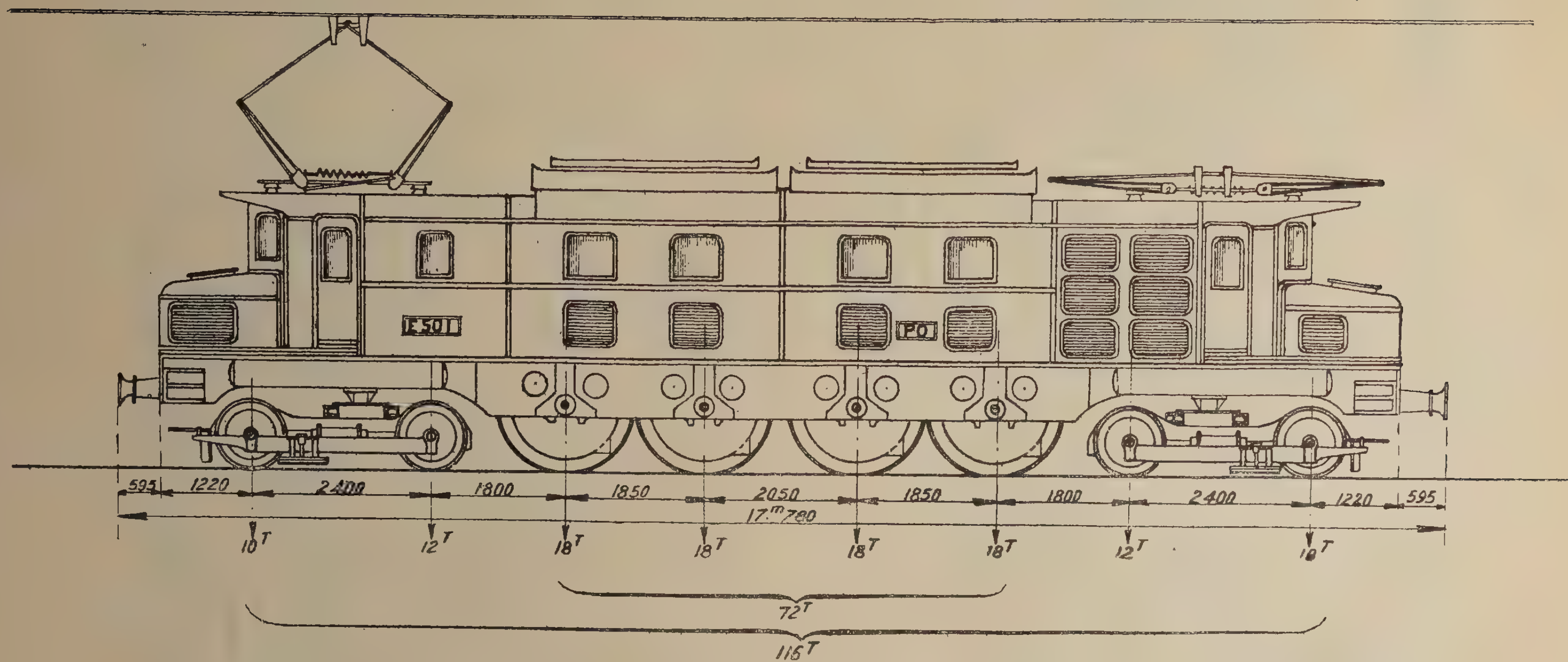


Fig. 16. — High speed electric locomotive, type 2 D 2-E 501 and E 502, built by the Brown-Boveri Company for the Paris-Orleans Railway.

There exists at least a dozen different arrangements which theoretically give a satisfactory solution of the problem. Nearly all include an intermediate link joined on the one hand to the spur wheel and on the other to the driving wheel and the connections are such that, as in the Oldham universal joint, side movement is free but the driving couples are transmitted. In a certain position the driving wheel can move vertically without displacing the intermediate link in a position at 90° from the last, the intermediate link alone moves.

But, on account of the angular displacements of the axle, at the present time there is hardly any really good solution other than those which include spherical articulations with a rationally designed system of lubrication. Other more simple designs are actually on trial and it is desirable that one of them should be perfected, as this detail is a cause of considerable maintenance costs.

On the two Brown-Boveri locomotives of the Paris-Orleans the method adopted was that of Mr. Büchli, which is kinematically perfect since, even with an excentricity of 10 cm. (4 inches) of the spur wheel to the driving wheel, there is a difference of less than 1 % between the speeds of these two parts; this solution is very satisfactory from a mechanical point of view, even though it seems complicated on account of the many spherical articulations : it has given every satisfaction in use.

In fact, these two locomotives behave remarkably well in the road and as their power is considerable they have a very great reserve which enables them to work nearly always at an output which they could maintain indefinitely.

We cannot insist too much here on the importance of always providing an adequate reserve of power on the engines which have to cover a regular service.

Locomotives 2C2-E 3101-3110 of the Midi Railway (fig. 17).

A new design has been adopted on the 2C2-E 3101 to 3110 locomotives of the Midi Railway Company, designed by the « Constructions Electriques de France ».

To raise the centre of gravity use has been made of motors with vertical shafts. Above each of the three driving axles two vertical twin motors each drive through a conical pinion a double toothed wheel keyed on the hollow shaft or quill. The transmission from the quill to the axle of each wheel is made by means of eight identical small rods working in tension and each one having as an elastic member at each end a spiral spring working in compression (fig. 18). These springs, thanks to their deflection, allow the small rods to take a considerable angle in all directions without the need of any lubrication.

Four of the small rods, B-B'-B_1-B'_1 (fig. 19) are parallel and connect the quill to two points A and A_1 situated at 180° on a floating ring [1].

The other four small rods C-C'-C_1-C'_1 are perpendicular to the first and situated on the same plane and they join the driving wheel to the two points D and D_1, situated at 90° to the two preceding ones on the same floating ring.

It may be seen that all movements of the axle relatively to the quill are rendered possible, provided that their amplitude does not exceed a certain amount.

These locomotives run remarkably stea-

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(1) Free in all directions and placed between the hollow shaft and the driving wheel.

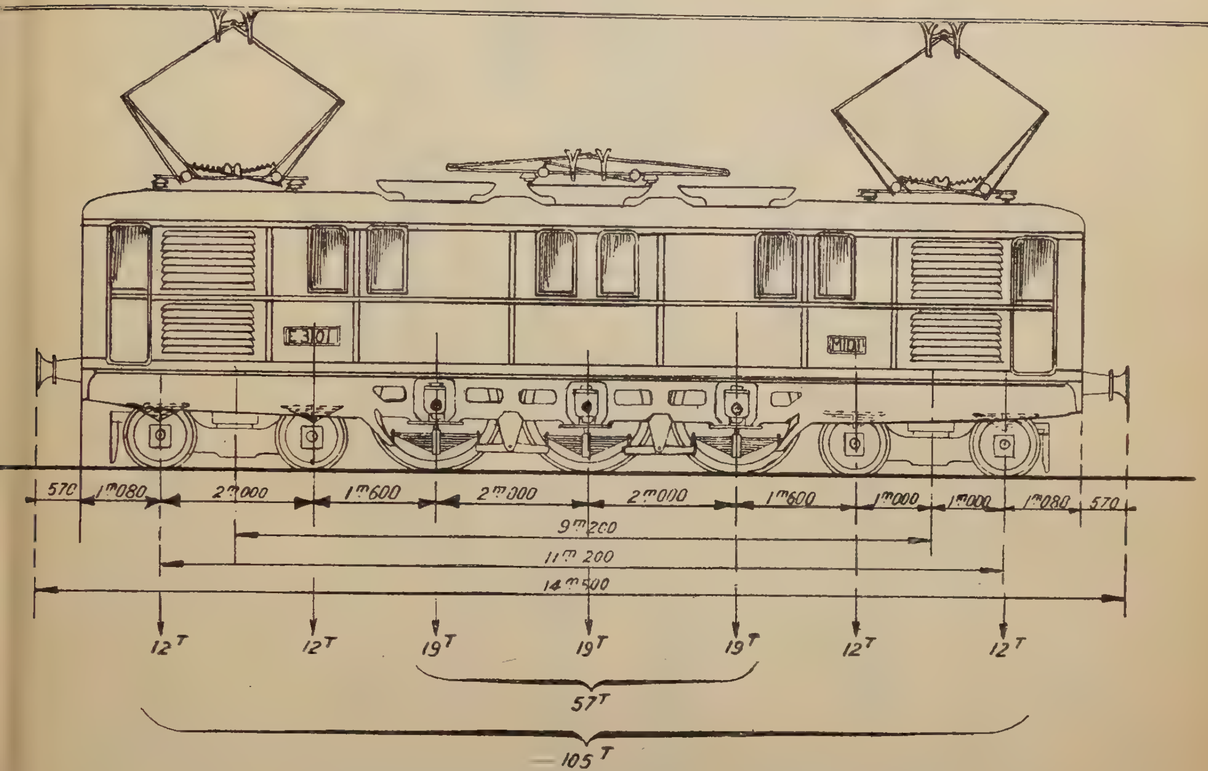


Fig. 17. — High speed electric locomotive, type 2 C 2, class 3101, built by the « Constructions Electriques de France » for the Midi Railway.

dily up to a speed of 144 km. (89.5 miles) the hour, the maximum reached under test.

High speed locomotives of the Paris, Lyons & Mediterranean.

The Paris, Lyons & Mediterranean has ordered for trial six high speed locomotives, two of different 2 BB 2 types and 4 of the same 2 CC 2 type. All these locomotives consist of a single frame of great length carried on two trucks coupled together. The bogies are of the usual Paris, Lyons & Mediterranean type and are self centering by inclined planes. Each axle is individually driven by two «Twin» motors carried on the truck and transmitting their power to a hollow shaft by means of a simple gear.

On the 2 BB 2-BE 1 locomotive, of a power of 2 000 kw., hour rate, designed by the « Batignolles-Oerlikon » group (fig. 20), the spring coupling is of the Oerlikon type with spring fitted connecting rods and spherical coupling (fig. 21); the gears are not fitted with any spring device.

On the 2 BB 2-AE 1 locomotive, of 1 900 kw. designed by the « Société Alsacienne de Constructions Mécaniques » (fig. 22) the suspension of the body

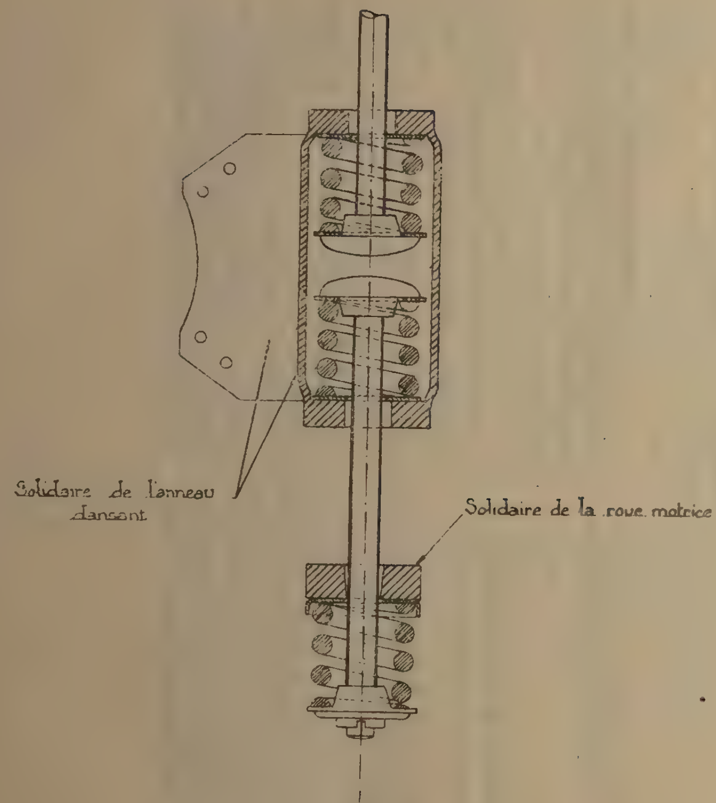


Fig. 18.

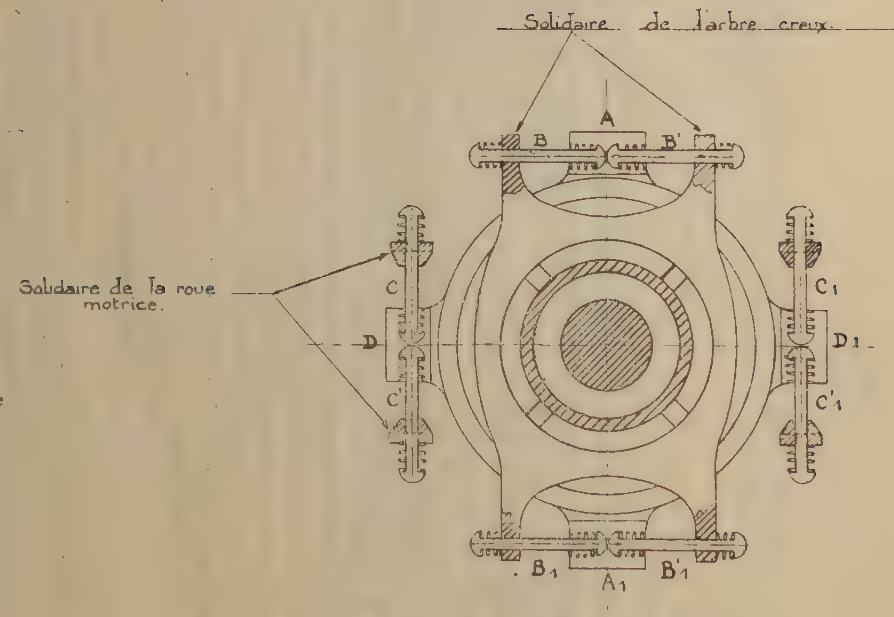


Fig. 19.

Figs. 18 and 19. — High speed electric locomotive type 2 C 2, class 3101, built by the » Constructions Electriques de France » for the Midi Railway. Flexible drive.
Explanation of French terms in figs. 18 and 19 : Detail etc. = Detail of small rod. — Solidaire... dansant = Attached to the floating ring. — Solidaire... motrice = Attached to the driving wheel. — Solidaire... creux = Attached to hollow axle or quill.

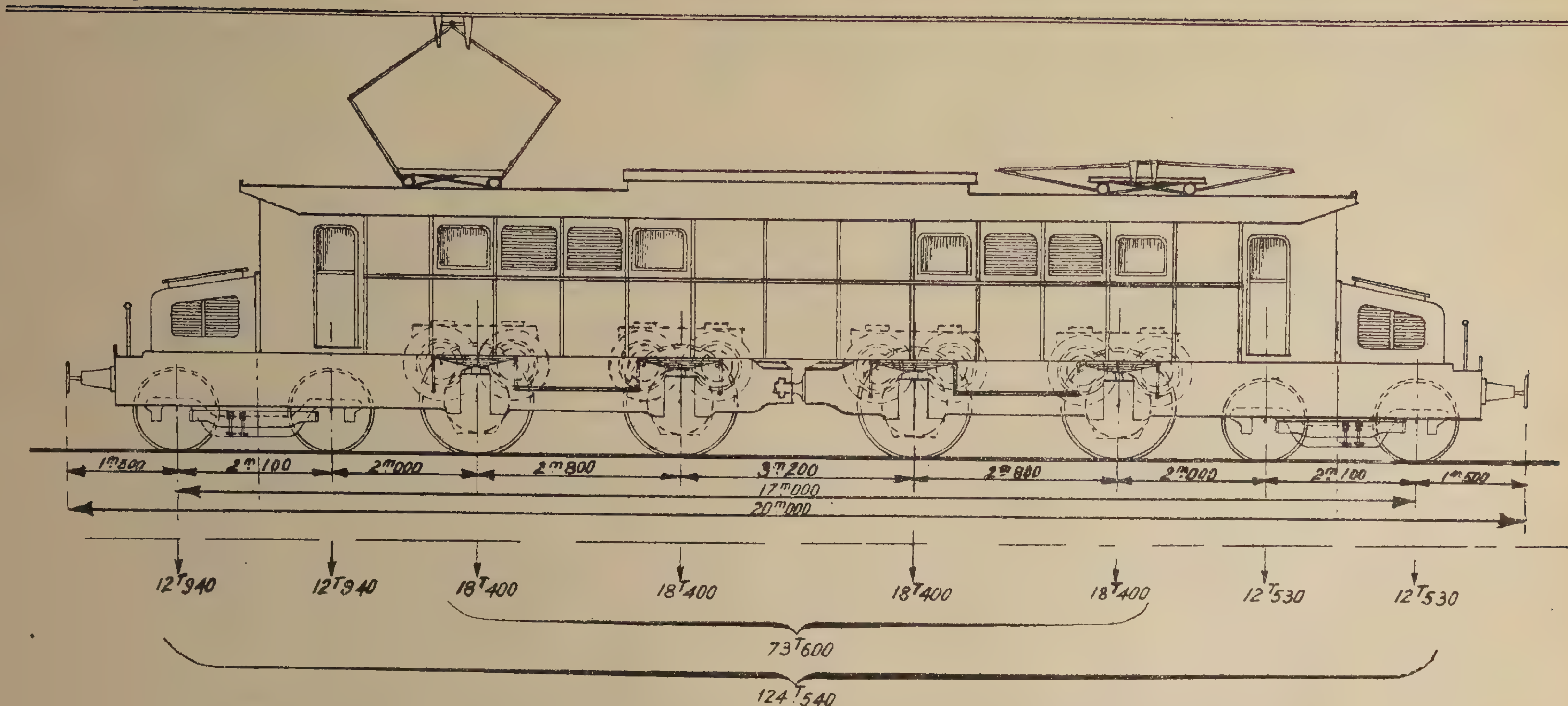


Fig. 20. — High speed electric locomotive, type 2 BB 2. BE 1, built by the « Société de Construction des Batignolles et Oerlikon » for the Paris, Lyons & Mediterranean Railway.

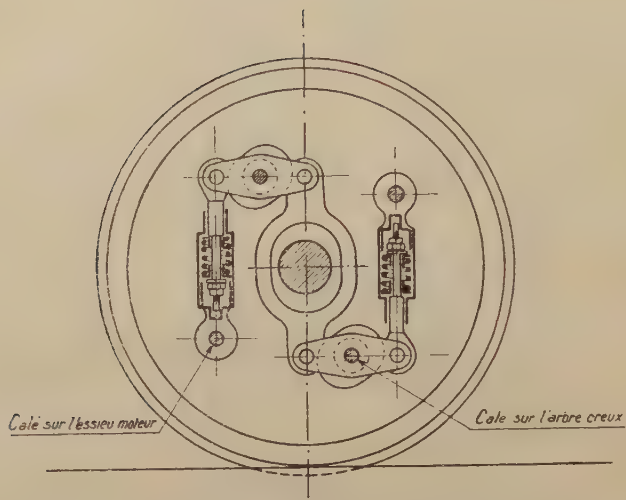


Fig. 21. — Electric locomotive, type 2 BB 2 (BE 1) and 2 CC 2 (AE 1 to 4), built by the « Société Oerlikon » for the Paris, Lyons & Mediterranean Railway. Flexible drive.

Explanation of French terms : Calé... moteur = Keyed to the driving axle.
Calé... creux = Keyed to the hollow axle.

on each truck is of the Midi type, that is to say with inverted pivots and lateral equalisers. The spur wheels are flexible and the couplings are of two types. On one of the bogies it is of a special type with small rods (fig. 23) and on the other it is made up of 6 springs fastened to the hollow shaft and to the wheel (Westinghouse type, fig. 23).

On the 2 CC 2-AE 1 locomotives 1 to 4, of 3 900 kw. one hour rating (fig. 24) designed by the « Batignolles-Oerlikon » group, which should run at a speed of 130 km. (80.8 miles) per hour, the frame is carried on each truck on an ordinary pivot with four spring supports. The spring coupling is of the Oerlikon type with small rods which has already been described, but the gear wheels are not fitted with any spring devices.

II. — ELECTRIC EQUIPMENT.

I. — Equipments.

Three types of control equipment are found on the French locomotives :

1° Electropneumatic control;
2° Cam shaft control;
3° Electromagnetic control.

1. *Electropneumatic control.*

This system has been used on the locomotives of the State and the Paris, Lyons & Mediterranean Railways, on all the BB locomotives, on the « Gearless » locomotive of the Paris-Orleans and on the new locomotives of the Midi Company.

In nearly all the cases in which this system is employed there are two quite distinct types on the same locomotive :

a) Separate contactors used each time

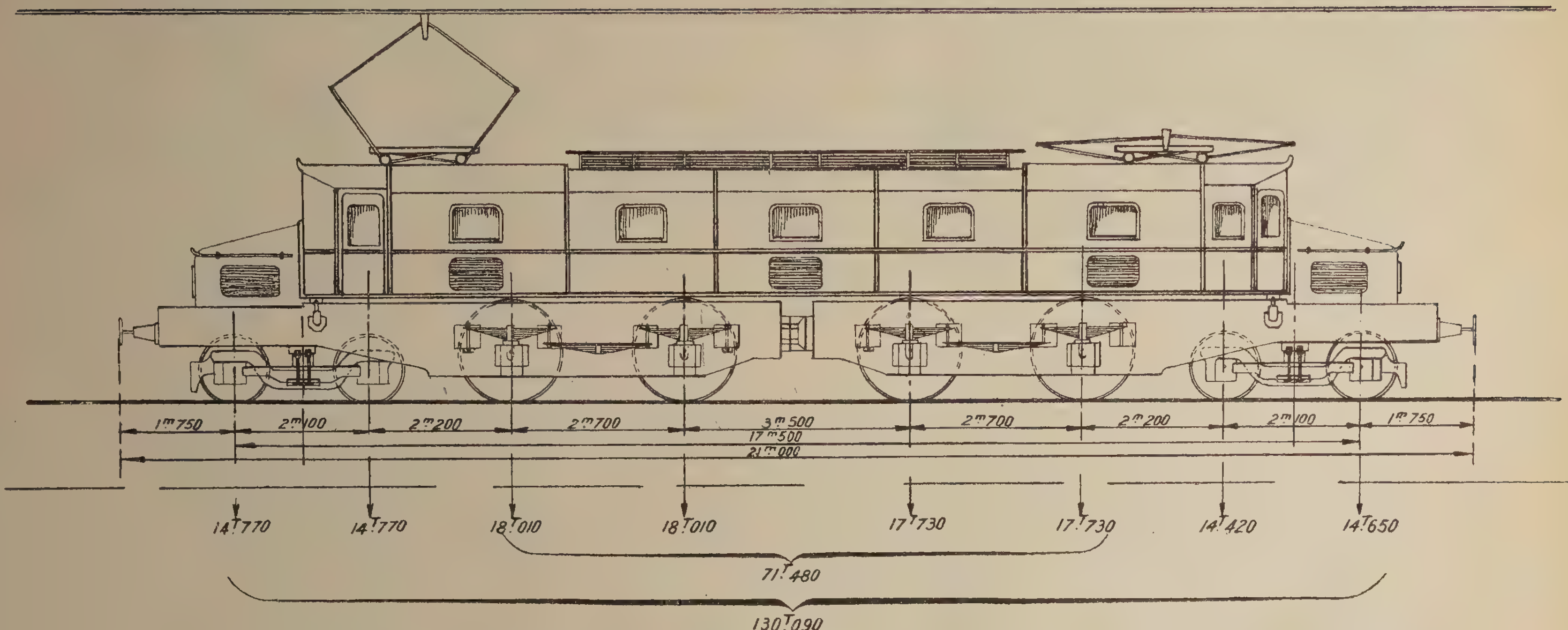
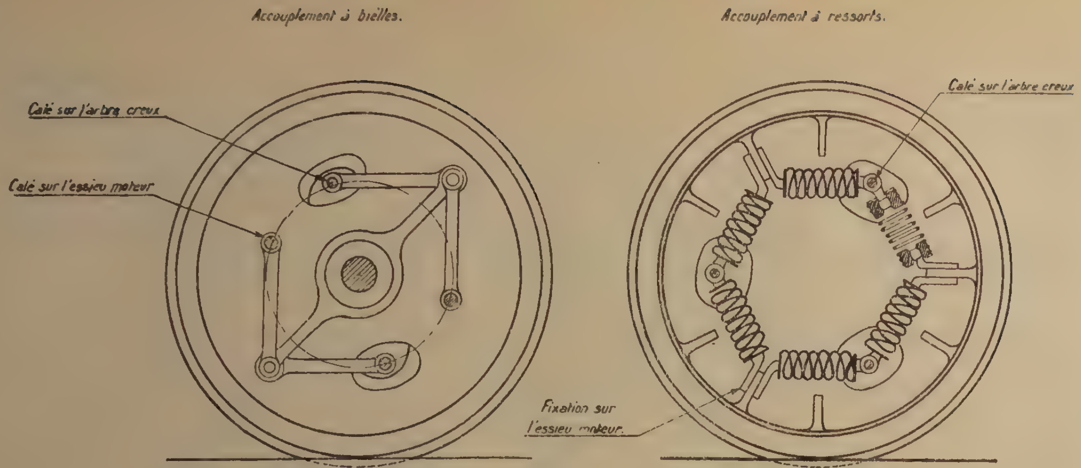


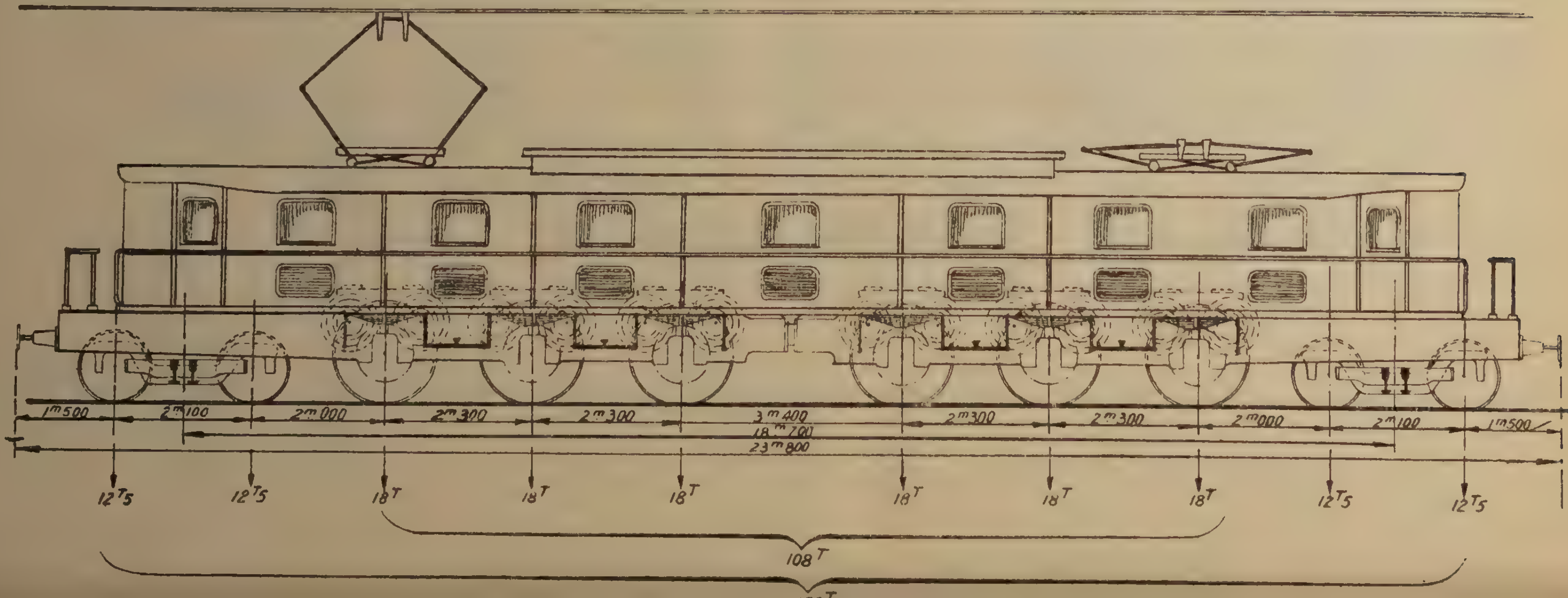
Fig. 22. — High speed electric locomotive, type 2 BB 2-AE 1, built by the « Société Alsacienne de Constructions Mécaniques » for the Paris, Lyons & Mediterranean Railway.



Explanation of French terms :

Accouplement à bielles = Coupling by rods.
Accouplement à ressorts = Coupling by springs.
Calé... creux = Keyed to the hollow axle.
Calé... moteur = Keyed to the driving axle.
Fixation etc = Fastened to the driving axle.

Fig. 23. — Electric locomotive, type 2 BB 2-AE 1, built by the » Société Alsacienne de Constructions Mécaniques » for the Paris, Lyons & Mediterranean Railway. Flexible drive.



there is question of cutting off current or varying the intensity of it by cutting in or out a resistance in its circuit;

b) Cam gear, with either two or three positions, which is not intended to break the main circuit such as the reversers, the make and break switches the shunt regulating gear for alteration of the shunt fields.

This cam gear is operated by a compressed air cylinder controlled by an electric valve. A source of electric energy, generally a battery of accumulators, of the nickel iron or cadmium-nickel type is all that is needed to assure the functioning of the electric valves.

2. *Cam shaft control.*

This system is used on the Morocco locomotives, on all the earlier locomotives of the Midi, and on two high speed locomotives of the Paris-Orleans.

In this control all the contactors are operated mechanically by a cam shaft which is usually driven by an electric low voltage servomotor.

The cam shaft can also make all the necessary couplings although certain types of equipment possess special coupling apparatus worked independently. The reverser is always independently controlled. The shunts also are generally controlled independently.

3. *Electromagnetic control.*

This type of control has been used on certain motor coaches of the State Railways, and on two experimental high speed locomotives of the Paris-Orleans.

By this system all the coupling and resistance cutting out contactors are controlled separately by electromagnets, the necessary current being either given by the current from a battery or the traction current itself when the pressure does not exceed 750 volts or the currant supplied by a motor converter set.

Results obtained with these different systems of control.

The electromagnetic system which has been employed on a limited scale in France has the inconvenience of requiring many interlockings and consequently being very complicated as regards auxiliary wiring. Furthermore when the contactors are operated by the traction current it makes the control directly dependent upon this traction current and subjects it to all changes of line pressure; it has also the inconvenience of throwing the full line pressure on to the control circuit when the motors are off.

The two other systems have been in general use on the French Railways and have given satisfactory results.

However the electropneumatic control system seems to be the better. The Midi Company in particular, whose locomotives were at first all equipped with cam shaft control, did not fit this system on its latest locomotives and has gone over to the electropneumatic control.

The reasons for abandoning the servomotor cam shaft system are the following: to feed the servo-motor which cannot make direct use of the high tension current, it is necessary to use a convertor set which transforms the high tension continuous current into continuous current at a suitable voltage.

This set can, as is the case in the 2 D 2. locomotives of the Paris-Orleans and the B. B. locomotives of the Morocco be combined with a battery of accumulators of relatively small capacity so as to avoid a failure in service due to any defect in the motor-generator set. Actually this ap-

paratus is the weak point of the cam shaft system.

So that the cam shaft may work properly its servo-motor must always be fed with current at nearly the same voltage. It is however difficult to obtain constant tension at the terminals of the low tension generator part of the set when the variations of pressure on the high tension feed line are considerable.

It must be admitted however that on railway companies which, like the Paris-Orleans, only allow of small variations of tension on the line, the cam shaft control system can give good results.

Another drawback of this system is that even small modifications of the control system result in very considerable alterations which are not required in the case of separate contactor systems, where moving a contactor or changing a few connections enables the desired result to be rapidly obtained.

The theoretical advantage of the cam shaft that interlocking is not needed must not be exaggerated. A rational grouping of the separate contactors and a logical use of the cam apparatus for the « position » details make it possible to obtain satisfactory simplicity with an electropneumatic control.

To sum up as far as the control equipments are concerned it would seem that according to the experience of the French Railway Companies, and in particular of the Paris-Orleans and the Midi, in the present state of the science, the best system of control is at present that composed of position cams, preferably with two positions or at the maximum three, for the couplings without interruption of current, and separate contactors for all the circuit breakers, all these parts being controlled electropneumatically.

The heart of the system is therefore an accumulator battery of nickel-iron or better still of nickel-cadmium cells of great robustness and easy to maintain. The operating power is compressed air which method has been tested and proved in the railway service and the supply is not likely to fail, all the electric locomotives being usually provided with two compressors to ensure the safe working of the brake. The working of the different electropneumatic control apparatus is positive and independent of the tension on the line and it gives the maximum of security. This system has also the advantage of the fact that the whole of the control circuit is under low tension, varying in practice according to the builder from 24 to 100 volts, thus greatly increasing the safety of the staff. All no load tests, and all inspection of the apparatus can be made with normal care, without the least danger and in the best conditions for finding any defective apparatus.

II. — Circuit breakers of normal action.

This apparatus is intended to complete or break a circuit under the most disadvantageous conditions which could be encountered in the normal working of this circuit. Amongst these apparatus the most important are the contactors or the switches which close or cut off the current in the circuits of the traction motors. In fitting these apparatus it must be remembered that they may have to cut out either a current equal to that corresponding to the conditions of maximum adhesion of the locomotive, *i. e.* a heavy current or a weak current in a circuit with a very high self induction and very small resistance. In this case, the case of breaking the circuit when running at high speed, there is not the least diffi-

culty, quite the contrary in fact. Breaking a highly inductive circuit (the case of the traction motors circuits) with a low density current has been one of the most difficult to solve of the practical problems with continuous high tension current.

One solution which seems satisfactory for breaking under normal conditions the traction circuits consists of making the equipment turn back by passing through all the intermediate positions in such a way as to definitely cut a circuit including all the motors and all resistances in series, that is to say a circuit of relatively low density with a suitable time constant.

In spite of this first precaution the Midi and Morocco Railway Companies have retained the two stage break. In the first step a contactor or switch opens and introduces a limit resistance into the circuit in addition to the starting resistances. During the second step one or several contactors or switches in series assure the final cutting of the current.

III. — Protection of the locomotives against electrical phenomena.

Electrical locomotives can suffer great damage through electrical phenomena; these phenomena are of two kinds :

— phenomena due to overvoltage,
— phenomena due to excessive current.

a) *Protection against overvoltage.*

Many devices have been and are still used : electrolytic lightning protector, condensers, discharge resistances, condensers shunted by resistances, a group of condensers, spark gaps and resistances, horned lightning arresters, coils, etc. Up to the present it is impossible to say whether these devices are efficacious against internal or external overvoltage on the feed lines. As far as direct flashes of lightning are concerned, in the present state of the science, there is no existing device which can assure complete protection beyond that which consists of a resistance placed directly between the line and the earth and which has the drawback that there is a constant loss of energy.

b) *Protection against excessive current.*

This is one of the hardest problems that requires solving on the public railways. In fact because of the nature of the service to be worked one is obliged to make use of very powerful substations, capable of supporting very high overloads.

As regards protection there are opposing schools of thought.

One of them only installs ultra-rapid throwout switches in the substations, for the following reasons :

In the case of a complete short circuit near a substation the density of the current can attain very considerable values which can be limited only by the use of special apparatus of which the most usual is the ultra-rapid breaker; on the contrary, if the fault is not dead to earth, or if it is at a distance from the substation, the current supplied by this latter may not exceed its normal value and therefore will not cause the protective devices to function.

The result is that if any thing occur on a locomotive the current is nearly always maintained on the line by the furthest substation, but its value is always limited and remains below that at which the throwout switches in these substations are set, the equipment on the locomotive having only to cut off this reduced current.

Cutting out in this way can then be

done by the action of the usual train control apparatus, instead of supplementary circuit breakers being necessary. The working of this arrangement is as follows : as soon as an overload relay operates it unlocks in turn all the resistance contacters of the locomotive which has the effect of inserting in the circuit starting resistances and the further limiting of the current which can then be cut off without difficulty by the line contactors.

This arrangement is only suitable for traction circuits; the auxiliary circuits are protected by the fuses who are sufficiently rapid in action to avoid on the one hand the apparatus in the substations coming out and consequently the line current being cut off and on the other hand damage to the circuits they protect. Also complete independance between the traction circuit and the auxiliary circuits is assured by this means, and the automatic elimination of the auxiliary circuit in which the defect arose, all of which minimises the resultant effects on the locomotive.

When electric traction at 1 500 volts was first used on the French Railways the majority of the locomotives were thus protected by a group of overload relays, ordinary switches, and fuses.

The Midi Railway Company recognized that this system could be inadequate and might cause energization and preferred the second solution of the problem which provided special safety devices on the locomotive.

The object of these devices is to cut off the current on the locomotive when the current is abnormal. On the Midi locomotives there is only one device of this nature per locomotive; it is of such a size as to be able to cut out a current equal to at least the sum total of the maximum current at which the circuit breakers are set at the two most powerful substations between which the locomotive in question could be running.

This special cut out works in two cases:

a) in the case of overload in any one of the high tension circuits of the locomotive, including the train heating circuit if there is one;

b) in the case of a short circuit in the interior and in any part of the locomotive.

The cut out is generally effected in two stages by a quick break throw out switch cutting off on resistance and by a second switch, the quick break cut out having to work :

1) under the action of the overload relays in *each* of the high tension circuits.

2) at the maximum.

The latest locomotives of the Midi Company, 40 of which have already been built and 100 identical in design are under construction, are provided with such protective devices. The results obtained on the first locomotives in service are entirely satisfactory.

IV. — Traction motors.

The particular feature of all the motors for heavy service under 1 500 and 3 000 volts is that they all have to be ventilated by separate fans. The only exceptions are the motors of the motor coaches which are self ventilated; it is however to be noted that these motors are then intended to work at 750 volts between terminals and are arranged with at least two in series.

The insulation used is mica for the armature, and mica with asbestos for the poles.

Some of the experimental locomotive motors are provided with compensatory windings.

In a general way, in the case of all makers, the 1 500-volt motors actually give every satisfaction, both from the point of view of heating and commutation. It has even been possible to keep up high speeds (110 km.. [68.3 miles] per hour) frequently enough with motors with the nose spring borne without damaging the collectors.

It can now be said that the problem of the 1 500-volt motor, of no matter what type, has been solved.

V. — Electric braking.

The question of electric braking has been and always is a matter of eager discussion between electric traction engineers.

It is however a matter on which everyone seems to be in agreement; the reason is that it is entirely useless to provide a system of electric braking on passenger locomotives for through services on the lines with easy gradients.

For passenger locomotives for stopping services or on heavily graded lines and for goods locomotives for working trains not fitted with continuous brakes, electric braking is of great value by reducing the wear of tyre and brake blocks, and by the increased safety.

Two systems are available :

— braking by regeneration;

— and rheostatic braking.

The first system is of value when, owing to the nature of the service, it permits an appreciable part of the current to be regenerated.

But it should be noted that to make the traction motors work as generators feeding current to the contact line it is necessary to excite them separately by means of a variable voltage independent exciter, or even by a traction motor specially alloted to this duty when braking (this method has not been made use of on French locomotives) the energy absorbed by the exciter has therefore to be deducted from the energy regenerated.

From the experience of the Midi and Morocco Railways it can be said that from the economic point of view the regeneration is not of great value on easily graded lines, nor even on those of saw tooth profile when the gradients are not very long.

But on lines where there are long gradients, and above all when the descending traffic is of greater tonnage than the ascending, regeneration becomes a matter of great value, as in the case of a line which runs between a mine in the mountains and a port. The Railways of Morocco have some lines like this and the energy regenerated by the descending trains is nearly 50 % of the energy absorbed by the ascending trains. On the Paris-Orleans whose electrified lines are all on the level the problem is of no import; on the Midi Railway the energy regenerated on a given gradient is only about 1/3 of the energy consumed. If account be made of the need for exciter sets, of the additional energy consumed by these sets when the braking is not being used, and of the increased price of the locomotives, it can be said that regeneration is of no value to this Railway Company.

It has therefore been abandoned for rheostatic braking. The Company has also been guided in its choice by motives of safety. Although no mishap on its electrified lines was due to regeneration, the Midi Company considered that this method of braking was not good enough for goods trains that were not furnished with automatic air brakes. In effect, if

during regeneration the locomotive or the substation between which it was running happen to cut out or if the current on the line happens to fail for any other reason, the braking stops abruptly which might be dangerous if the driver should lose his head and did not immediately stop his train by all the means remaining at his disposal.

To avoid such mishaps, certain railway companies, and in particular the Paris, Lyons & Mediterranean (which is interested in regeneration because it buys its current from outside sources and works lines with very steep gradients) have arranged a safety system which causes all the mechanical brakes to act when the current fails or the machine switches out while regenerating.

The Midi Company has thought it better to make the electric braking completely independent of the line current.

All the movements of the apparatus necessary for electric braking are worked by means of a battery of accumulators of nickel-iron alloy, and the braking is of the rheostatic type. Each locomotive is able to hold on a given section a train of tonnage equal to that which it can draw up the same section at the one hour rate; this results in the braking resistance having to absorb powers of the order of 1 000 kw. The problem was solved by the builder, the C. E. F., in a excellent manner, as well with cast iron as with soldered resistances. The chief difficulty was to reach as rapidly as possible a stable working temperature so that the braking effort does not alter when running with the brakes on. The problem then becomes one of ventilating the braking resistances, and was most difficult to solve in view of the large quantity of energy to be dissipated as heat.

Rheostatic braking can also be utilized to stop the train. Some of the equipments tried have given valuable results although thay have not yet been perfected. Some of them have even given rise to the hope that it will be possible to recover energy during the stop, which would be useful for frequently stopping trains.

VI. — Current collecting mechanisms.

Except for the Paris, Lyons & Mediterranean which uses the 3rd rail except on sidings in the stations which are equipped with overhead lines, the other Railway Companies of France and her Colonies, which employ continuous current at 1 500 or 3 000 volts for traction purpeses, have adopted overhead lines.

The current is collected from the overhead by means of pantographs with or without horns. The pressure on the contact wire is 7 kgr. (15.4 lb.) on the Morocco Railways, 9 kgr. (19.8 lb.) on the Midi, 8 to 10.5 kgr. (17.7 to 23.1 lb.) on the Paris-Orleans and 10 kgr. (22 lb.) on the Paris, Lyons & Mediterranean.

On the Railways two leading ideas have been followed for working the pantographs.

The Paris-Orleans, Paris, Lyons & Mediterranean and the State Railways, in the case of pantographs fitted up for running over tracks equipped with overhead lines, lift the pantograph by means of compressed air which compresses the springs giving the necessary pressure on the contact line. The lowering of the apparatus is caused by gravity when the air is allowed to escape from the lifting cylinders.

The Midi and Morocco Railway Companies on the contrary prefer to lift the pantographs by means of springs which are always under compression and assure

the necessary pressure on the contact line; the pantograph is lowered by means of compressed air which counterbalances the effects of the spring.

They considered that this method was preferable because it made it unnecessary for the driver to pump air by hand when taking up the working to lift the pantograph and hold it up until sufficient pressure is obtained from the compressor in the reservoirs. Further, lowering by compressed air allows the pantograph to be handled as rapidly as desired by giving the air cylinder suitable dimensions whereas when lowering by gravity at high speeds the pantographs do not come down freely but have a tendency to float up and down.

Several types of pantographs have been used, but the most common is the Broussouse-Faiveley type which is exclusively used by the Midi, the Morocco, and the Paris, Lyons & Mediterranean and in many cases by the Paris-Orleans which also uses pantographs made by Oerkilon and Thomson-Houston. This design has all its joints fitted with ball bearings electrically bonded. It has been made either to be lifted by springs or compressed air; on the Paris-Orleans and the Paris, Lyons & Mediterranean it is of the hornless variety.

No matter of what type it is this pantograph maintains a sensibly constant pressure on the line at no matter what height the line is between 4.50 and 6 m. (14 ft. 9 in. and 19 ft. 8 1/4 in.)

The rubbing bands of all the pantographs on French locomotives are made of bands of copper and the lubrication is by a mixture of stiff grease and graphite.

The Paris, Lyons & Mediterranean locomotives and the State locomotives of 750 volts usually pick up their current by means of collector shoes on a 3rd rail.

The Paris, Lyons & Mediterranean's collector shoes pick up on the top of the third rail whereas the State uses the universal type by which the shoe works either above or below the rail, this being the standard arrangement of the State Railways.

VII. — Various auxiliary apparatus.

On locomotives furnished with cam shaft equipment the auxiliary fittings: fans, and compressors, are generally either mounted at the end of the motor-generator shaft, furnishing the control current, or in the case of the compressors, driven by low tension motors fed by the low tension motor generators of this set.

In the case of electro-pneumatic equipments which do not require any rotaries, the fans and compressors are driven by special motors directly on the 1 500-volt supply. These motors are usually started without bringing into the circuit any starting resistances, a simple protection resistance being permanently in the motor circuit.

To diminish the current taken at starting and to protect the collector against the rush of current at starting which always acts on the same blades with the piston compressors the Midi Railway Company has placed a DEM progressive starter between the motor and the driven equipment.

OPERATING RESULTS.

According to the results obtained on the Midi since 1922, and on the Paris-Orleans since 1925, the electric locomotives as a result of using two sets of men can run two to two and a half times the mileage of steam locomotives of the same class and give a more regular service and one

more pleasant to the traveller. This regular running is due above all to the reserves of power making it possible to make up any delays much more easily than steam engines which depend upon the state of their boilers and the quality of coal used.

None the less up to the present serious failures have been two to three times as frequent as with steam engines, but it is probable that they will diminish and then almost completely disappear when the equipment is in thoroughly good working order.

In particular on the BB locomotives electrical failures represent 91 to 99 % of the total; mechanical defects are therefore very rare. On the contrary for high speed locomotives, the proportion of electrical failures is about 63 to 75 % according to the types, which proves that the mechanical defects are relatively more frequent.

Inspection and upkeep expenses.

Midi. — Certain parts are inspected every week, others only every month and even every three months.

Besides this the engines are lifted after: 60 000 km. (37 300 miles) for the BB goods, 100 000 km. (62 150 miles) for the BB passenger and express locomotives.

Paris-Orleans. — Ordinary inspection :

— every 10 days for motor coaches,

— every 8 to 15 days according to the service worked for the BB locomotives,

— every 4 days for locomotives working express trains.

General overhaul :

— every 120 000 km. (74 600 miles) for motor coaches and BB locomotives,

— every 140 000 km. (87 000 miles) for high speed locomotives.

Light repairs :

60 000 to 70 000 km. (37 300 to 43 500 miles) between two general overhauls.

The cost in 1928 for repairs and the upkeep of the electric locomotives and motor coaches are shown in the following table (average figures of the Paris-Orleans and Midi):

KIND OF WORK.	Cost per passenger train-kilometre (per passenger train-mile).
Repair and upkeep of electric locomotives and motor coaches . . .	0.20 to 0.25 fr. (0.32 to 0.40 fr.).
Running repairs of electric locomotives and motor coaches. . . .	0.45 to 0.55 fr. (0.72 to 0.88 fr.).

CONCLUSIONS.

To sum up, the locomotives with motors supported by the nose are very satisfactory for all services in which the maximum speed does not exceed 80 km. (50 miles), and in exceptional cases 90 km. (55.9 miles) (or at least up to a continuous rating of 400 H. P. per motor); it has even been possible with suitable gear ratio to run up to 100 km. (62 miles). The locomotives run very

steadily when out on the line up to this speed; however the actual experience of the French Railway Companies is that it is not possible to be sure that different parts of the locomotive, especially the motors, will not suffer at such high speeds, and result in heavy upkeep expenses. These locomotives have the advantage of being moderate as regards upkeep and first costs.

For higher speeds it is necessary to use locomotives with the motors fully spring borne which are more costly and complicated. Satisfactory results have been given by various types but there has not been sufficient experience for any one to be selected as the best. The only locomotive with the motors not spring borne (the gearless locomotive of the Paris-Orleans) has not been in service long enough for any definite opinion to be expressed upon it; it has the benefit of very great simplicity but nothing can yet be said about its behaviour on the track.

From the electrical point of view, the electropneumatic control is completely satisfactory; the purely electro-magnetic control has also given satisfaction where it has been tried; it has however only been used on a small number of locomotives.

The rheostatic braking is to be recommended in every case except for express passenger service over lines with easy gradients where its use would be of no value. As regards regeneration, the results are somewhat variable; it would however be of value for the trials to be continued, as it should be possible to obtain, especially in the case of mountain lines, appreciable savings of current. The experiments that are being carried out in braking the trains electrically are giving encouraging results.

Company				FRENCH STATE.	MOROCCO.	
Type of locomotive				BB. Passenger. Goods.	BB. Goods.	2 C 2 Fast trai
Number of locomotives of this type				...	10	10
One hour rating.	Maximum field.	Power, H. P.		1 080	1 360	1 91
		Tractive effort, kilogrammes		5 700	6 960	6 60
		Speed, kilometres per hour		...	53	7
		Current (amperes)		..	...	1 20
	Minimum field.	Power, H. P.		...	1 400	1 91
		Tractive effort, kilogrammes		...	5 580	4 80
		Speed, kilometres per hour		..	68	12
		Current (amperes)		...	...	1 20
Continuous rating.	Maximum field.	Power, H. P.		540	1 000	1 00
		Tractive effort, kilogrammes		2 800	4 620	4 44
		Speed, kilometres per hour		...	59	8
		Current (amperes)		...	...	84
	Minimum field.	Power, H. P.		...	1 040	1 40
		Tractive effort, kilogrammes		...	3 660	3 00
		Speed, kilometres per hour		...	77	13
		Current (amperes)		...	...	84
Length over buffers, metres				12.140	11.850	14.50
Total wheel base			in metres.	8.800	8.350	11.20
Wheel base, main trucks			in metres.	...	...	4
Wheel base, leading bogies			in metres.	...	2.800	2
Diameter of driving wheels			in metres.	1.200	1.400	1.75
Diameter of carrying wheels			in metres.	...	...	0.90
Number of motors				4	4	3 double m
Dimensions of motors.	Height		in metres.	..	...	2.20
	Width		in metres.	...	..	1.35
	Length		in metres.	...	...	1.60
Weight of one motor, metric tons				4.100	4.214	11
Total weight, metric tons				63	73	105.60
Adhesive weight, metric tons				63	73	58
Weight on each driving wheel, metric tons				15.750	18.250	19.30
Weight on each bogie axle, metric tons				...	...	11.70
Weight per horsepower, one hour rating, in kilogrammes				58	53.5	55

MIDI.			PARIS, LYONS & MEDITERRANEAN.			
BB. Passenger. 1st series.	BB. Goods. 2nd series.	BB. Passenger trains. 3rd series.	1 CC 1 Fast trains.	2 CC 2 Fast trains.	2 BB 2 Fast trains.	2 BB 2 Fast trains.
50	40	40	161 AE. 1	262 AE. 4	242 BE 1	242 AE. 1
1 400	1 400	1 400	2 450	5 340	2 700	2 450
8 400	13 000	11 900	12 000	18 000	13 600	12 000
47	29	32.5				
800	800	800				
1 400	1 400	1 400	2 450	5 340	2 700	2 450
7 600	8 900	10 000				
70	43.5	41	65	97	70	70
800	800	800				
1 400	1 000	1 000	1 950	4 150	2 450	1 900
5 400	7 600	7 350	8 650	13 020	11 350	8 400
52.5	32	37				
560	560	560				
1 000	1 000	1 000	1 950	4 150	2 450	1 900
3 200	5 000	5 600				
85	53	71	110	130	110	110
560	560	560				
11.870	11.870	12.870	20.580	23.800	20.000	21.000
8.350	8.350	8.950	17.430	20.600	17.000	17.500
			2.940	4.600	2.800	2.700
2.800	2.800	2.950	2.440	2.100	2.100	2.100
1.400	1.400	1.400	1.240	1.590	1.590	...
...	...	...	0.905	1	1	...
4	4	4	6	6 double motors	4 double motors	4 double motors
0.940	0.940	0.984	...	...	...	...
1.058	1.058	1.090	...	...	...	...
1.057	1.057	0.920	...	...	...	...
3.400	3.400	4.400	3.900	...	...	...
68	72	76	118.940	158	124.540	130.090
68	72	76	96.350	108	73.600	71.480
17	18	19	16.060	18	18.400	17.870
...	...	...	...	...	...	...
48.500	51.500	54.300	48.500	29.600	46.200	53

Company			PARIS, LYONS & MEDITERRANEAN (continued		
Type of locomotive			1 CC 1 Passenger.	1 CC 1 Passenger.	1 CC Passen
Number of locomotives of this type			161 BE 10	161 CE 10	161D 10
One hour rating.	Maximum field.	Power, H. P.	2 450	2 360	2 36
		Tractive effort, kilogrammes	18 600	18 000	18 30
		Speed, kilometres per hour	...	...	...
		Current (amperes)	...	...	...
	Minimum field.	Power, H. P.	2 450	2 360	2 36
		Tractive effort, kilogrammes	...	...	...
		Speed, kilometres per hour	45	41	4
		Current (amperes)	...	...	...
Continuous rating.	Maximum field.	Power, H. P.	1 950	1 700	1 70
		Tractive effort, kilogrammes	13 500	11 250	12 30
		Speed, kilometres per hour	...	...	...
		Current (amperes)	...	...	...
	Minimum field.	Power, H. P.	1 950	1 700	1 70
		Tractive effort, kilogrammes	...	...	...
		Speed, kilometres per hour	80	80	8
		Current (amperes)	...	...	...
Length over buffers, metres			20.580	21.200	21.60
Total wheel base		in metres.	17.430	17.800	17.54
Wheel base, main trucks		in metres.	2.940	4.920	4.32
Wheel base, leading bogies		in metres.	2.440	...	...
Diameter of driving wheels		in metres.	1.240	1.390	1.43
Diameter of carrying wheels		in metres.	0.905	0.850	1
Number of motors			6	6	6
Dimensions of motors.	Height	in metres.	...	...	...
	Width	in metres.	...	...	...
	Length	in metres.	...	...	...
Weight of one motor, metric tons			3.900	...	5.26
Total weight, metric tons			129	125	126.26
Adhesive weight, metric tons			105	102	107.34
Weight on each driving wheel, metric tons			17.5	17	17.89
Weight on each bogie axle, metric tons			...	...	...
Weight per horsepower, one hour rating, in kilogrammes			52.700	53	53

PARIS-ORLEANS.

E 2 D 2 Fast trains.		E 2 D 2 Fast trains.		E 2 CC 2 Fast trains.	BB. Passenger.	BB. Passenger.	BB. Passenger.	BB. Passenger.	BB. Passenger.
01 1	402 1	501 1	502 1	601 1	1 to 80 80	101-180 80	201 to 208	214 16	224-240 16
200	4 400	3 600	3 600	2 710	1 640	1 720	1 420	1 680	1 500
7 200	17 600	14 800	15 200	8 940	10 320	9 880	8 870	10 320	9 500
65.5	68	65.5	63.7	82	43	47	43.8	44	42.5
2 500	2 600	2 160	2 160	1 710	1 000	1 060	900	1 040	950
				mean field.					
4 300	4 400	3 720	3 720	3 000	1 520	1 720	1 464	1 680	1 540
3 240	15 200	12 560	12 800	9 300	7 440	7 680	7 740	8 080	8 200
88	78	80	78.5	87	55	60.5	51	56	50.5
2 600	2 600	2 240	2 240	1 850	920	1 060	920	1.040	930
3 380	3 600	3 200	3 200	2 040	1 320	1 500	1 240	1 320	1 240
3 000	13 600	12 720	13 000	6 060	7 760	8 400	7 200	7 520	7 200
70	71.4	68	66.5	91.5	46	48.5	46.5	47.5	46.5
2 020	2 100	1 920	1 920	1 275	800	940	780	816	780
				mean field.					
3 440	3 520	3 340	3 340	2 280	1 280	1 460	1 260	1 320	1 260
9 800	11 040	10 640	10 800	6 342	5 840	6 240	6 240	5 600	6 240
95	86	85	83.5	97	59	64	54.5	63.5	54.5
2 010	2 100	2 000	2 000	1 380	780	900	792	816	792
16.040		17.780		19.140	12.700	12.500	13.100		12.754
13.160		14.150		15.938	8.800	8.740	8.500		8.500
5.550		5.750		2.850	...	...	...		...
2.200		2.400		2.440	2.700	2.800	2.800		2.800
1.750		1.750		1.200	1.250	1.350	1.350		1.350
0.970		0.970		0.915	...	...	..	...	...
4		4		6	4	4	4	4	4
1.800		1.360		0.865	0.886	1.120	0.950	1.03	0.950
1.540		1.280		1.250	0.870	1.048	0.976	1.010	0.976
1.800		1.360		1.425	1.000	0.910	0.965	0.940	0.965
.500	13.500	7.540		5.320	4.100	5.020	4.465	4.765	4.465
.950	131.730	121	125	113	69.200	76.700	77.400	78	73.200
72		72		78	69.200	76.700	77.400	78	73.200
18		18		13	17.600	19.175	19.350	19 500	18.300
.490	14.930	11	12	8.160	...	...	...	...	...
		13.500	14.500	9.250	...	...	...	...	...
	30	33.6	34.7	39	42.200	44.500	54.500	46.400	51.500

[625. 23]

REPORT No. 2

(All countries except America, the British Empire, China, Japan, Belgium, France and their Colonies)

ON THE QUESTION OF ALL STEEL COACHES. COMPARISON WITH VEHICLES BUILT OF WOOD (SUBJECT VIII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Martin GARCIA-VARO,

ENGINEER OF THE ANDALUSIAN RAILWAY COMPANY,

and

Pablo FRAILE,

ASSISTANT TO ROLLING STOCK CONTROLLER OF THE NORTH OF SPAIN RAILWAY.

Figs. 1 to 12, p. 1772 to 1793.

The questionnaire which we sent through the Permanent Commission of the International Railway Congress Association, to the various Railway Companies, members thereof, was drawn up in agreement with Messrs Lemon (E. J. H.), Lancrenon and Vallancien, reporters of the same subject for the other countries, for the next meeting of the Congress.

Of the ninety-one Administrations, with a total of 127 394 km. (79 160 miles) of lignes to whom we sent the questionnaire thirty-four with 108 043 km. (67 136 miles) have replied. Several other Companies and Manufacturers of Rolling Stock of whom we have asked information, have also been good enough to supply it.

We wish to express here our thanks to all these administrations for the information, drawings and photographs, which form the basis of our work and which have enabled us to draw up the present report.

The way the question is worded, shows that it could be divided into two distinct parts :

A. — Stock entirely of metal, and

B. — Comparison of such stock with wooden vehicles, subjects that we will deal with separately, following the order of the questionnaire sent to the various Railway Administrations.

A. — Carriages built entirely of metal.

When classifying the replies to the questionnaire, we have taken into account not only those which deal with vehicles into the composition of which certain parts in metal are used, but also others in which one uses wood or other materials for the interior lining, partitions, flooring etc. Briefly, we take as all metal vehicles all those which form one unit of body and frame, built up of parts in metal permanently connected together by rivetting, welding, or other methods.

(1) Translated from the French.

Fig. 1. — Italian State Railways. — General view of body framing of a metal coach.

I. — Utility of all-metal construction.

Metal stock can be considered under three different aspects; safety of the passenger, durability and robustness, and economy in maintenance.

As regards safety, the whole of the Railways are in agreement that steel stock should be used, because the great strength of metal bodies hinders or makes more difficult telescoping or crushing after accidents, the resistance offered being contributed to by the rigid connection of the body and the frame. The splintering of the woodwork, which is so dangerous for passengers, does not occur, and finally, in such vehicles, there is no danger of fire,.

As regards life and indeformability, although logically these should not be greater than in the case of vehicles with wooden bodies used up to the present, as the metal stock has been only a short time in service, it is not possible to give any precise information on these points; on the other hand, nothing has occurred

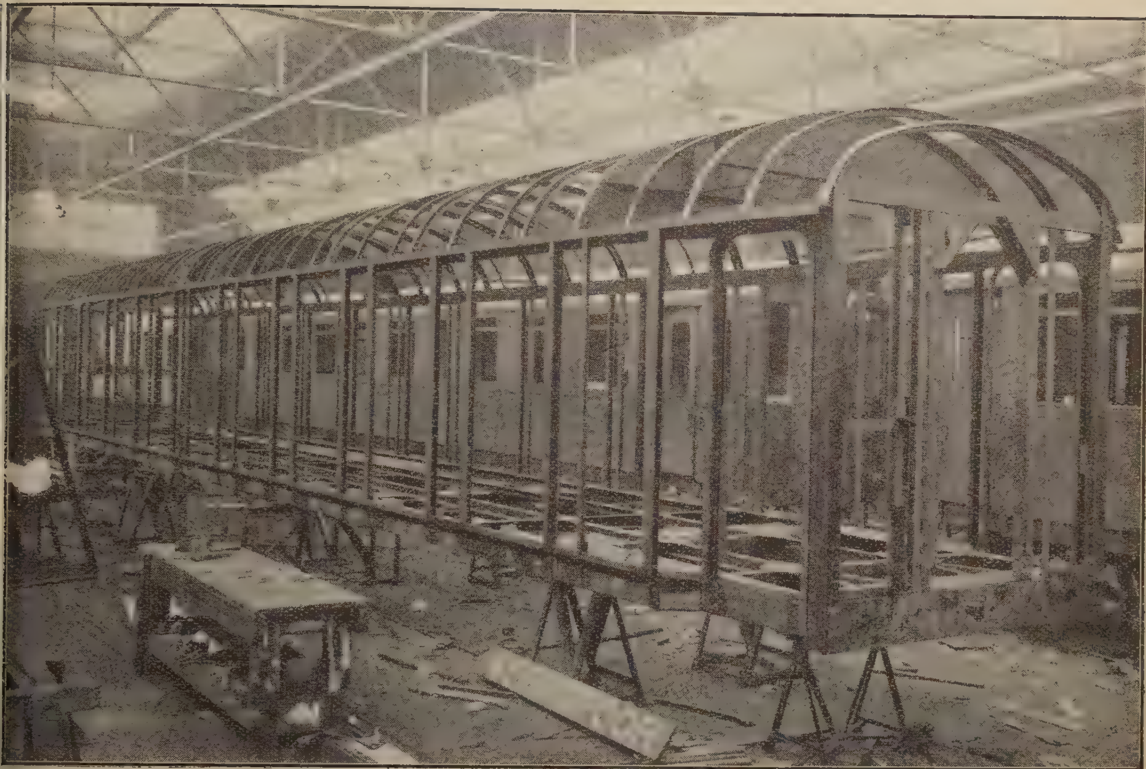


Fig. 2. — Netherlands Railways. — Metal body framing of class A. B. 7201-09 coaches.

so far to justify any contrary opinion, and it is in this sense that most of the Railways consulted expressed themselves.

As regards maintenance of the coaches, for the same reason it has not been possible for us to obtain any accurate information : there is no doubt however that the rigid connection of the various parts of the metal body, will show a definite advantage over the assembly of the same details in wooden bodies, the troubles with which are being still further increased by the difficulty of procuring wood of proper dryness and seasoning; it also avoids the drawback of having to form stocks of wood, such stocks being reduced to the minimum in the case of metal coaches.

In spite of their small experience with regard to this matter, several railways which have used metal coaches for the last five years, are satisfied that they have shown a saving in the cost of repairs.

As regards the cost that corrosion of the plates might cause, it is still too soon to form any opinion although so far nothing of the kind has been observed.

Several Companies speak of a possible reduction in the weight of metal coaches, but this does not appear to be generally

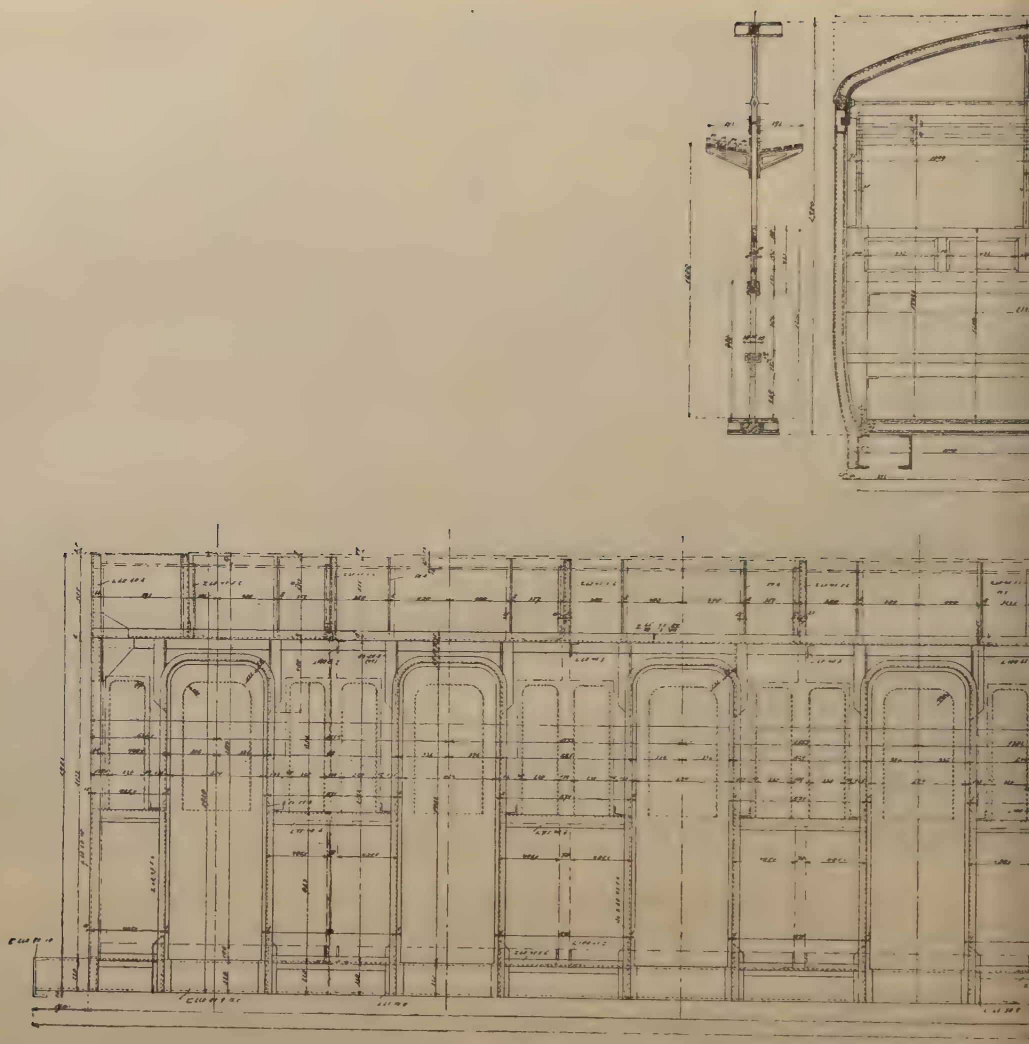
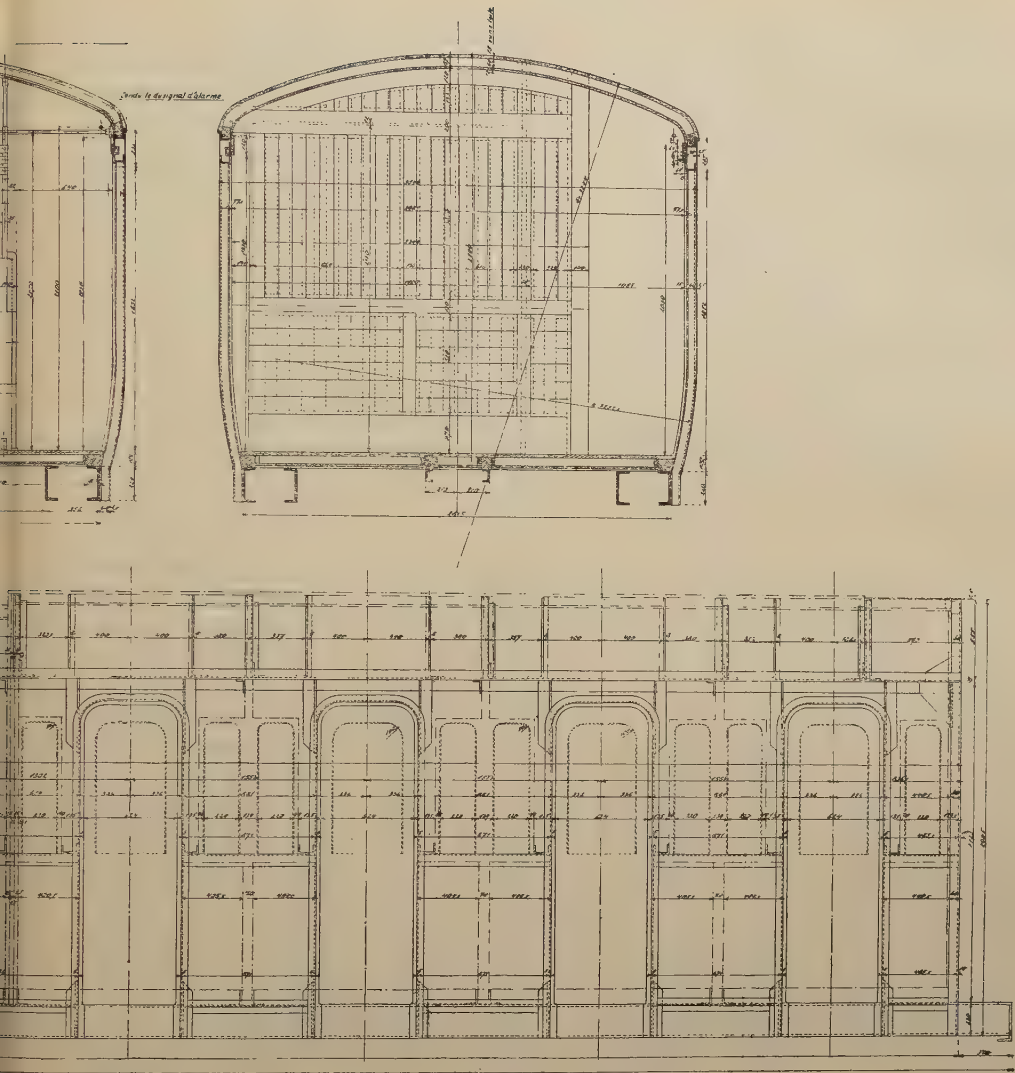


Fig. 3. — Portuguese Railways. — Boc

proved when comparing these vehicles with coaches with wood bodies as we shall see later on.

In general it appears that the various Railway Administrations tend towards the construction of metal stock; several Companies in the North of Europe, when balancing the advantages and disadvantages of the two methods of construction, wonder if it is desirable to adopt steel stock for their countries.

The Administration of the Finnish State Railways is of the opinion that the very severe climate in their country dur-



d third class non-corridor metal coaches.

ing the winter would result in greater cold in steel stock; it is also afraid that moisture would condense on the inside of the coaches, and thinks that metal vehicles are heavier and more costly. This latter drawback, we think, applies equally to most of the Railway Administrations.

II. — Types of metal coaches in service, under construction, or being designed.

The greater part of the metal vehicles in service in the countries included in the present report have been built on the principle of building each side of the carriage as a trellis girder, the flanges of

which are formed at the top and the bottom by the cornice and the sole bar of the vehicle, the trellis being formed by the vertical pillars and the outside covering sheet, forming a Vierendeel girder, the two sides united one to the other by the roof carlines, and the cross bearers of the frame, thereby giving an assembly similar to that of a bridge girder.

In most of the vehicles so built, access to the interior is given at the end; among vehicles of this type of construction are those of the Italian State Railways, shown in figure 1, and the Dutch vehicles from A. B. 7201-09 and C. 7201-06 built in 1928, figure 2.

In all these vehicles, the partitions, the sides, and the roof, have been strongly braced to the walls of the vestibule and the end of the body, so as to obtain great strength to resist violent buffing stresses and draw gear snatches, and in the case of accidents, to ensure the vehicle retaining its shape as much as possible.

The same method of construction has been used with certain modifications for vehicles with side doors or with large central entrances. In these two cases it has been necessary to make good the absence of uprights at the openings by strengthening the cornice and the inside lining of the body and the door pillars. This is what has been done by the Portuguese Railways, in the case of their four wheeled vehicles (see fig. 3).

The same method of construction has been used by the North of Spain Railway for its metal coaches and its trailer coaches on its electrified line.

These coaches, as can be seen in figure 4 in addition to the doors at the end are provided with large central doors so as to facilitate the entrance and exit of passengers of the fast timed trains with frequent stops in which they are used.

The International Sleeping Car Company has adopted an entirely different method of construcion. It uses a strong frame, of the centre box girder type with the ends in cast steel, upon which is mounted a light body the pillars of which are connected to the lower edges of the body and these in turn to the cantilever brackets on the centre girder.

The Serbian State Railways, state they use a very strong frame, but have not, however, supplied any details about the form of construction adopted.

The Roumanian State Railways use the method of construction first described, but their frames are strengthened up so as to make it possible to use a lighter body.

It can therefore be said that the Railway Companies of the Countries covered by this report, use as a rule, the type of construction wherein the body is designed to form a trellis girder, strengthening the frame more or less according to the opinion of the Company.

The International Sleeping Car Company alone uses a very strong centre girder frame which offers perhaps greater resistance to buffing and draw gear stresses which naturally must be transmitted along the centre line of the frame.

III. — Methods and materials of construction.

Most of the metal carriages of which we have received details are built with rolled sections with flat plates for connecting them together, punched, bent, and curved plates and cast steel. The coaches shown in figures 1 and 2 have been built of these materials.

Rolled sections are currently used for the sole bars and cross members of the frame; for the body pillars, rolled sections in the forms of L, U or Z or bent

plates are used. The roof carlines are made of the same materials.

Figure 5 illustrates the carriages used on the North of Spain Railways, in which bent plate is used for the uprights, the cross braces, and the carlines; rolled sections are only used in the frame and the cornice.

A number of Companies including the International Sleeping Car Company form the end of the frame in a single cast steel block.

In the same way other Companies such as the North of Spain and the North of Milan use cast steel in assembling of the body.

Steel pressings are used widely for the body pillars, carlines and windows frames. It is used in this way by the Czecho-Slovakian State Railways, the Egyptian State Railways and the International Sleeping Car Company.

For the outside covering, steel plates, generally of 3 mm. (0.118 inch) thickness are used, and 1 to 2 mm. (0.039 to 0.078 inch) thickness is used for the roof.

In the early days, the floor of steel coaches was similar to that in wooden vehicles; thick boards were laid on the upper side, and thinner on the lower, the space between being filled with insulating material such as cork, celotex, etc., and the whole protected against sparks produced by the brakes and the electric equipment.

There appears to be a tendency in modern vehicles to build the floor in corrugated steel plate, covered with heat resisting material such as decolite, or with the grooves fitted with strips of compressed cork and in some cases covered with cork sheets in order to give double protection against noise and temperature changes.

Light metals, such as aluminium, and various alloys are used in some vehicles for the interior lining; the North of Spain, amongst others, has used aluminium in this way on its motor coaches and trailers.

In the same way, the International Sleeping Car Company uses duraluminium for the roof of some of its coaches, and alpax in certain parts, not subjected to high stresses such as window frames, and metal parts of bed frames etc.

The Czecho-Slovakian State Railways use duraluminium for the window frames, and the North of Milan for the interior divisions.

Most of the Railways however do not appear to use alloys or light metals in the construction of their carriages.

Although the use of light metals or alloys gives a reduction in weight, their use should be considered very carefully, in order to avoid the risks of corrosion of plates made of such materials; the alloys which appear likely to give the best results, are Silumin and alpax.

The same care should be taken when using aluminium sheets for the interior and exterior linings.

There is a further difficulty in that aluminium sheet is difficult to paint, the surfaces having to be very carefully cleaned before the first coat of paint is applied.

In cases where high stresses have to be carried, duraluminium should be used in preference.

The various details forming the body of steel coaches are as a rule joined up by riveting, and only very rarely by bolting together.

As well as riveting, electric welding is used currently, and this appears to be the best way of preventing humidity getting into the insides of the joints of the plates; spot welding is also used; oxy-acetylene welding is little used.

There is a difference of opinion amongst the various Railways with regard to the head of the rivet; certain Companies do not allow the head of rivets to be

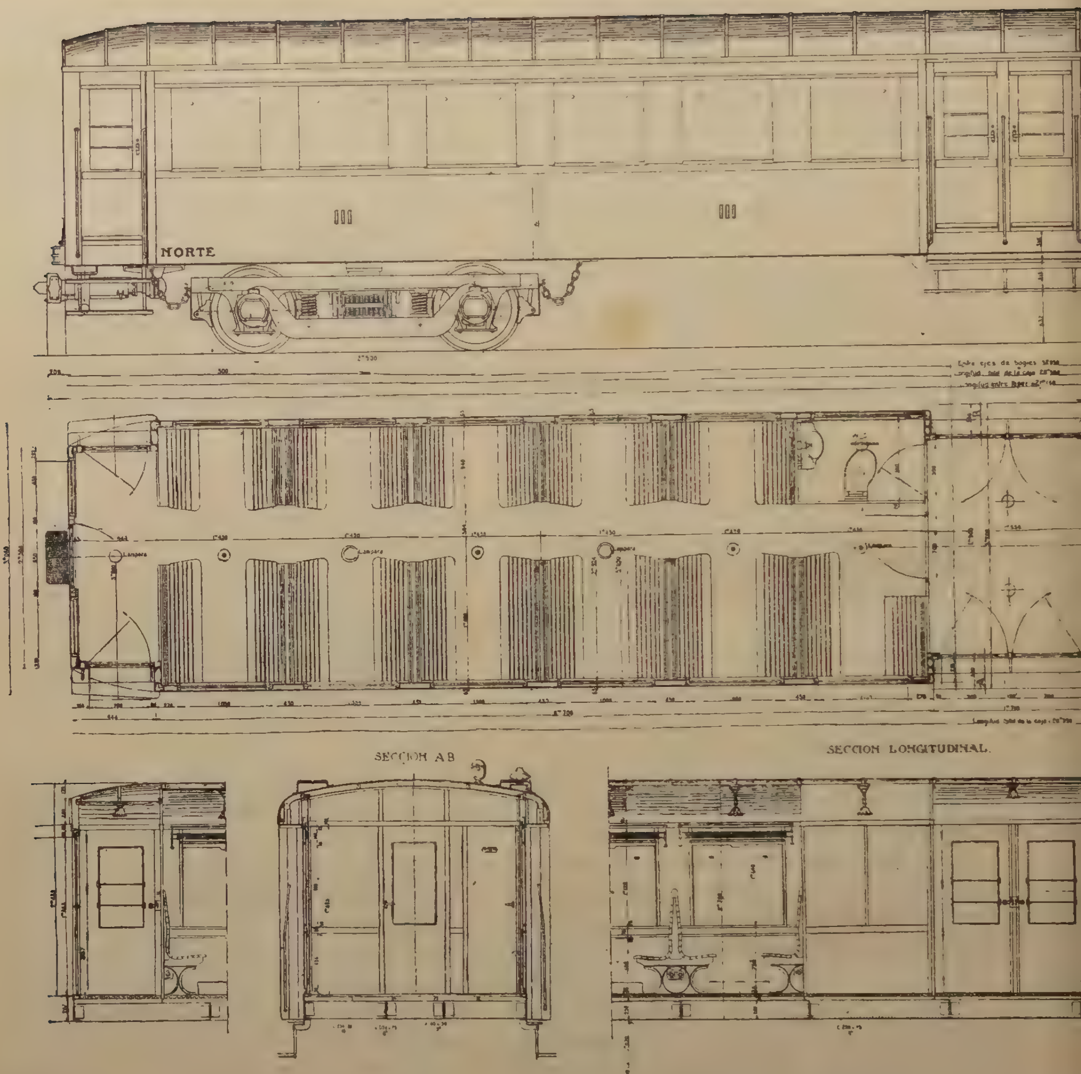
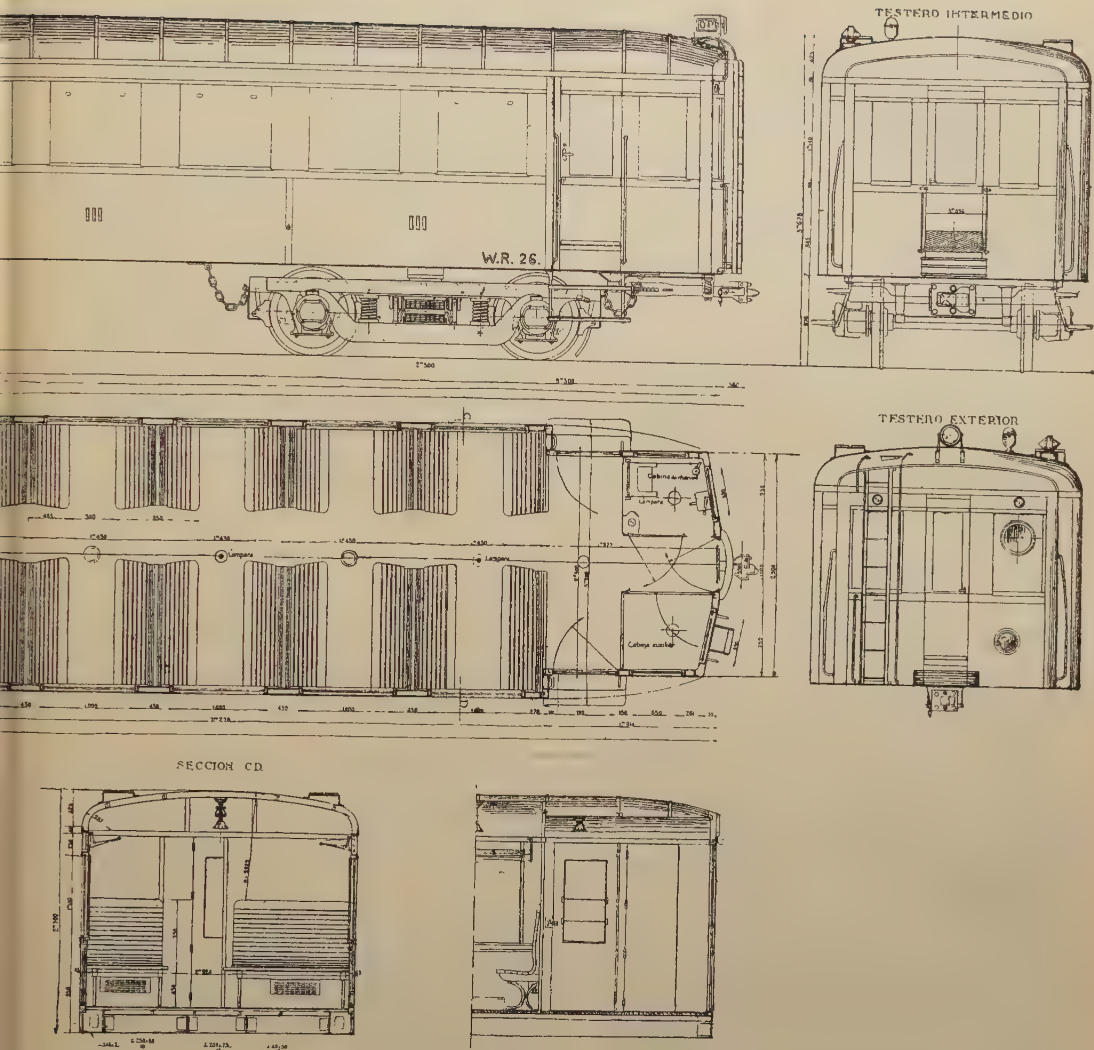


Fig. 4. — North of Spain. — Third cl

seen on the outside, or, only use them in the case of third class coaches, owing to their unsightly appearance; some Companies, on the other hand, allow the heads of the rivets to be seen so as to make the vehicle appear stronger.

Figures 6 and 7 are exterior views of two carriages; one of the Italian State Railways with counter sunk rivet heads, and the other of the Egyptian State Railways with the rivet heads visible; both have a pleasing appearance.

There does not appear to be any good reason why one or other arrangement



ler coaches for electrified surburban lines.

should be recommended in preference, especially if the counter sunk rivet heads are used with joint straps of sufficient thickness.

In practice, there is no difficulty in using countersunk rivets.

When the rivet heads are visible, there is the disadvantage that cleaning is more difficult and also the paint on the projecting parts wears off before that of the rest of the vehicle.

In most of the steel carriages used in the countries dealt with in the present report, wood has been used for the interior

lining, partitions, roof, inside doors, and the floors.

In some instances the interior partitions are in metal from the waist rail to the floor and in wood above, with occasionally metal framing and reinforcements.

There is a tendency, however, to reduce as much as possible the use of wood in the inside partitions and to use it solely for decorative purposes.

The passengers too prefer the interiors finished in wood to those finished in metal, not only because of its more comfortable appearance, but also because in moist climates, moisture condensing on the interior metal makes it unpleasant to touch.

On several Companies the ends of the body, and the vestibules are all metal, as is the reinforcement of all the inside partitions; some Companies are thinking of making new stock entirely of metal.

Various methods are used to protect the plates against rusting; as a rule they are covered with several coats of lead paint, or of lead colour, or of special anticorrosive antiseptic paints; the parts out of sight also receive in certain cases a coat of bituminous paint.

In some cases the plates are thoroughly cleaned by means of a sand jet, and then given several coats of oil paint.

The plates near the windows are also protected by means of a thin sheet of copper, so as to prevent any water from coming in contact with the sheeting of the coach.

Some Companies use special copper bearing steel, which appears to be either rust proof, or at least less subject to rusting.

In other cases, the Companies are content to treat the metal coaches with the ordinary methods of protection; lead paint, or other means of protecting the sheets against rust.

In certain countries, where the climate is dry, such as in Egypt, there is no necessity to take this aspect of the question into account.

The paints used for outside work on steel coaches are usually of two classes, lacquers or enamels, and nitrocellulose.

The first have been most currently used up to the present, and have been varnished, giving good results. As however, a number of Companies who have used nitrocellulose paint have been very satisfied therewith, this method is becoming general, and there are many Companies who have either adopted it, or have made tests with it to satisfy themselves as to the results to be obtained.

It must however be remembered that if this process gives good results on flat surfaces the coating of paint will tend to crack at the edges and to come away in angles, and ultimately result in blisters.

IV. — Inside fitting of the coaches.

Generally speaking, there is very little difference between the inside equipment of steel coaches and those built of wood. Wood, lincrusta, pegamoid, etc. is used for this purpose.

In the case of luxury vehicles, the interior decoration is carried out in mahogany with marquetry panels using rare woods. In first class compartments, mahogany, lincrusta, etc., is used as a rule. For second and third class coaches, pitch pine is generally used.

A general tendency to suppress all mouldings as far as possible, is observed.

The ceilings, as a rule, are white; in luxury vehicles and those of first class lincrusta is frequently used; for the other classes the roof sheets are left visible, and are painted.

The lining out of the corridors, and of the vestibule ends, is almost identical with that of the compartments in most vehicles.

The interior decoration is secured to the body framing by means of wood or fibre blocks, and wood screws.

In the case of coaches with interior divisions, the decoration is generally like that of other vehicles of the same class built of wood.

In certain vehicles for short distance working and for suburban service, the inside walls are not covered, the plates being painted with enamel paint; the inside of the toilet is, as a rule, painted in white enamel. The lower part of the wall of the toilet compartments, are, in a number of vehicles, covered with steel panels in vitreous enamel, or stove enamel; in others they are fitted with tiles. The floor of the toilet compartment is usually formed of tiles, of Eubolith, or in some cases, marble, or even of asphalt.

The ventilators in use on the wooden coaches have also been used by many Companies on the metal stock; torpedo ventilators are used, lateral ventilating plates, Flettner ventilators and louvre ventilators built up with pieces of glass. For some vehicles electric fans have had to be used owing to the lack of capacity of ordinary ventilators resulting from the greater conductibility of the steel, particularly in the case of vehicles running in hot countries.

In steel coaches, it has been necessary to counterbalance their excessive conductibility by using insulating material applied between the inside and outside sheetings, the insulation being either by means of thin asbestos mattresses, or felt, or cork, or asbestos cardboard, granulated cork, or similar products such as celotex, salamander, etc.

In countries, where in summer the temperature is very high, a number of Companies are not satisfied by the methods used up to the present, as is shown by the replies to the Questionnaire in the case of the Portuguese Railways. On this subject, the Egyptian State Railways are now making tests to decide what colour should be used, for painting metal coaches in order to reflect the heat.

Care must also be taken to guard against cold in the case of metal stock, by increasing the capacity of the heaters, or by fitting additional heating; the systems used are those employed on the wooden stock, that is to say, hot water, high or low pressure steam, and electricity.

The decoration is generally like that of the wooden coaches; special woods, bronzes, artistic photographs of National landscapes etc., mirrors, artistic lincrusta, upholstery etc. When metal plates are used in the interior, they are painted in colours which harmonise with the remainder of the decorations, so that the general appearance is pleasing to the eye.

The figures 8, 9, and 10, show the interior decorations of the compartments, corridors, and toilets of a first class steel coach belonging to the Italian State Railways.

The insulating material placed between the lining sheets also damp out vibration, and diminish the sonority of the vehicle.

With the same object various Companies insert felt pads between the floor and the linoleum covering it; it is also essential that the riveting of the various parts of the body and frame shall be thoroughly and carefully carried out, as is pointed out with reason, by the Yugoslavian State Railways.

It appears that in the case of well kept permanent way, steel vehicles do not set up

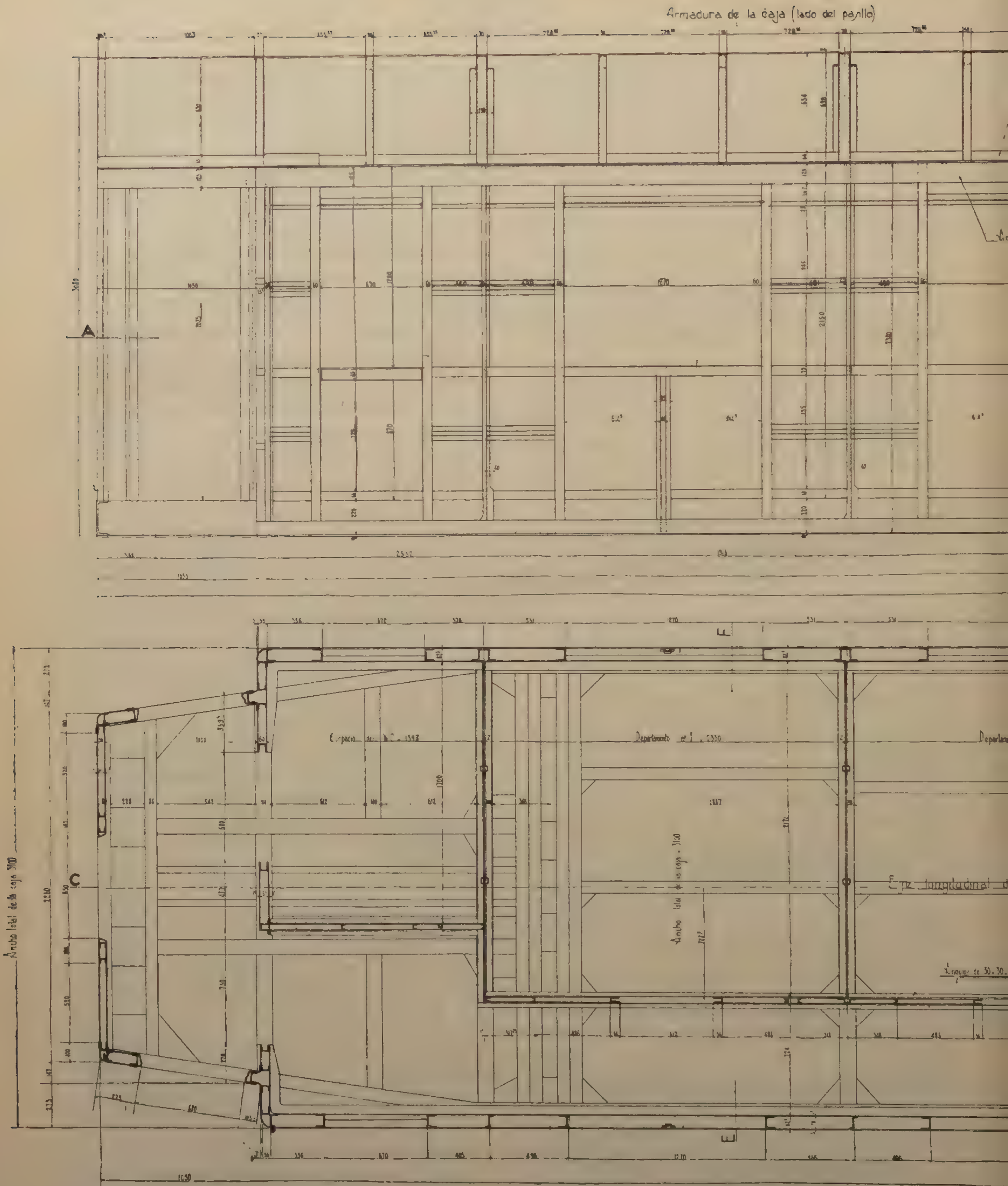
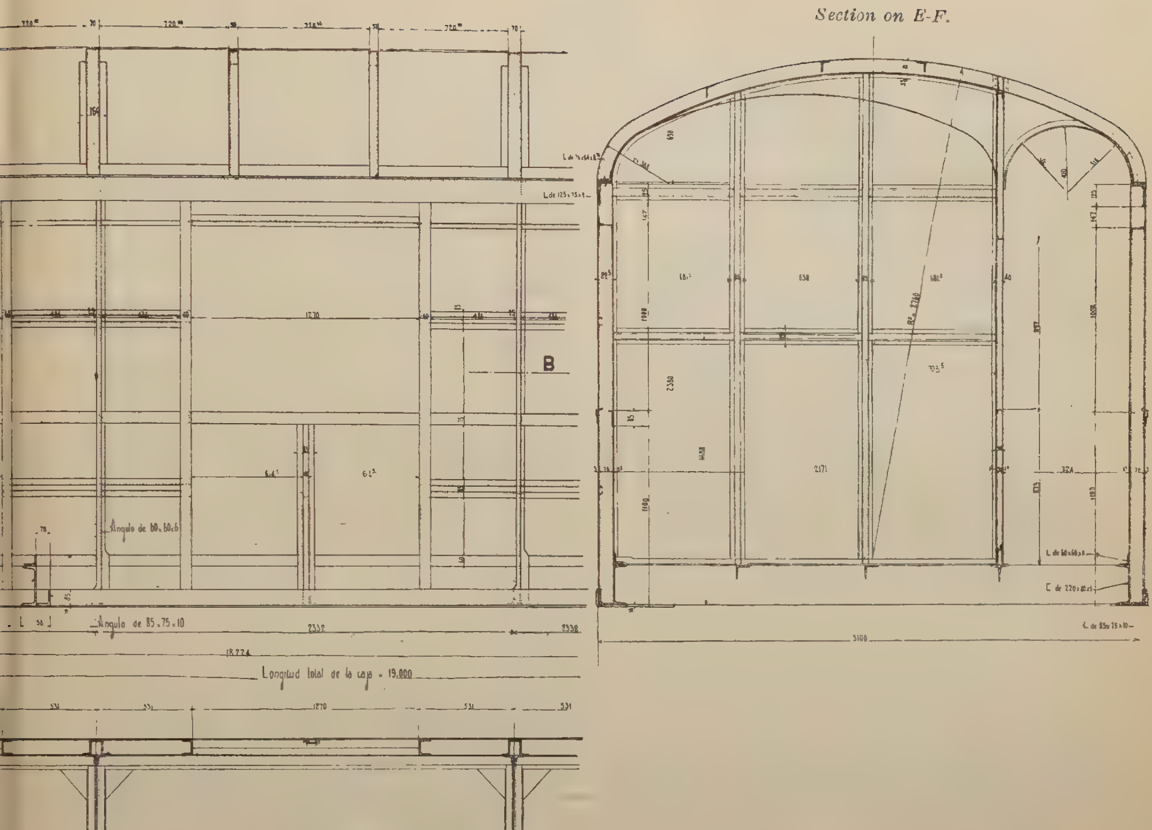


Fig. 5. — North of Spain. — First cla

Body framing. — Plan. —



n class AA FHV numbers 1001 to 1020.

rridor side. — Cross section.

any more noise from the passengers' point of view, than wooden vehicles. On this point the Czecho-Slovakian State Railways point out that drumming can be reduced by using wooden casings.

In most of the coaches of which we have received information, the water tanks in the toilet compartments are put in position, or removed, by taking down the inside ceiling of this compartment, and withdrawing the tank through the door or through the window. The ceiling of these compartments is so arranged that this work can be done easily.

Some Companies, such as the Roumanian State Railways, have arranged openings in the roof of these coaches through which the tank can be withdrawn or examined.

In certain countries, where the climate is cold, the water in the tanks has to be heated in order to prevent freezing during the severe winter frosts, either by using warm air from the compartment, or by placing radiators so as to heat the tanks.

V. — Results obtained in service.

The experience with steel coaches is not yet sufficiently great for any well founded opinion upon them to be given. We have however, not received any unfavourable report; the whole of the Companies when replying to the Questionnaire, state either that the coaches have not been in service long enough for them to express an opinion, or they report the good results they have obtained with such stock. The Italian State Railways the Egyptian State Railways, and the International Sleeping Car Company, are definitely of this latter opinion.

Relatively speaking, very few serious accidents have occured in trains in which steel coaches are formed, but when such accidents have occured, the steel stock has offered greater resistance than those with wooden bodies.

The International Sleeping Car Company, inform us that in a serious derailment of one of its trains de luxe, the brake van with wooden body was broken up, whereas the steel coaches only suffered slight damage.

In Yugoslavia, after another derailment, when picking up a steel coach which had been dragged more than 200 metres (220 yards) it was found no serious damage had been done to it.

The Italian State Railways, who have sent interesting remarks with regard to various accidents in which trains with metal coaches have been involved, have been able to appreciate the good behaviour of these vehicles under such circumstances.

We will quote two cases only in support of this opinion.

The carriage B. I. Z. 20 024 which was derailed at Prato, on the 18 August 1928, was turned completely over on its side. The only damages it suffered were a pillar twisted, and some windows broken; of the thirty passengers it carried two only had slight contusions.

During the collision of a train with an engine at Formia, the 7 September 1928, carriage 10 085 had one of its vestibules completely broken up; the passengers in the compartments of the vehicle, did not come to any harm; the damaged platform was empty, fortunately.

The photographs, figures 11 and 12, give some idea of this accident.

Other accidents, which we cannot enumerate here in order not to make this report too long, have demonstrated the superiority of the steel coaches over those of wood; in the case of the latter furthermore, the consequences are more to be feared when they are fitted with gas lighting.

Although at present it is still impossible to supply precise information on the subject of the ease with which repairs can be carried out, and on the cost of maintenance of steel stock, such upkeep, at the present time, appears to be easier to do, and less costly, than in the case of wooden vehicles; in case of accidents the damage is very localised.

As in addition up to the present rusting of the plates and loosening of the rivets does not appear to have occured in such a way as to cause the least concern, we can take it that their life is very great and that the maintenance of the bodies of metal coaches should be reduced as a rule, to that of painting.

B. — Comparisons with coaches having wooden bodies.

It is difficult to make between metal coaches and wooden coaches comparisons having any real value; each Company when getting out its plans for new carriages introduces different alterations for various reasons; certain of them, in order to give greater comfort to the passengers; the others, endeavouring to obtain by new lay outs a better use of the stock, from an operating point of view, and this naturally causes a certain confusion, which makes it difficult to deduce the consequences.

We have made a comparison between two classes of coaches, and drawn up the two tables given below, in which are shown the various details of some carriages of different countries included in the present report, endeavouring to show for each country, similar vehicles in wood and steel, and eliminating those of similar type in order to avoid useless repetition.

From these tables it will be seen that in general there is an increase in the weight of metal vehicles as compared with those in wood, and consequently, an increase in the dead weight to be hauled per passenger. This increase, however, has not much importance, as we must take into account the fact that in recent constructions care is taken to give the passengers better comfort and more room, and this means larger dimensions of the coach, a more elaborate decoration, and consequently a greater luxury. As a matter of fact, the lay-out of metal coaches does not show much difference from that of similar carriages built in wood, and they are used for the same services.

As regards the cost price of metal and wooden carriages, the comparison is rather unfavourable towards the former, the cost being generally higher.

* * *

In this description, we think we have given a general idea of the principal features of the metal coaches of the various Companies who have replied to the Questionnaire, and think that from what has been given above, the conclusions that we now propose to set out can be deduced.

It would appear desirable that all coaches should be built as a rule, for the future, entirely in metal, owing to the greater safety they give the passenger in case of accident in view of their greater resistance to deformation and to the fact that they are not affected by fire. The fact that their cost is greater will be made good by this advantage and by their lower cost of maintenance and repairs.

The dead weight per passenger to be hauled appears to be greater than that of similar stock with wooden bodies; but in this the steady growth which began long ago, in giving more room to the passengers and in making them more comfort-

Fig. 5 (*continued*). — North of Spain. —

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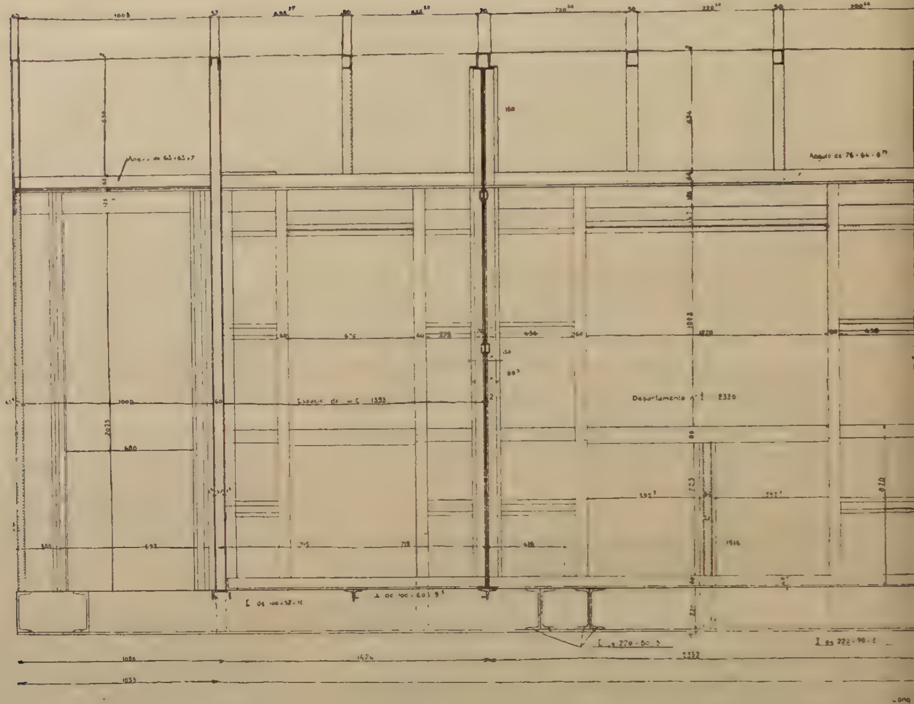

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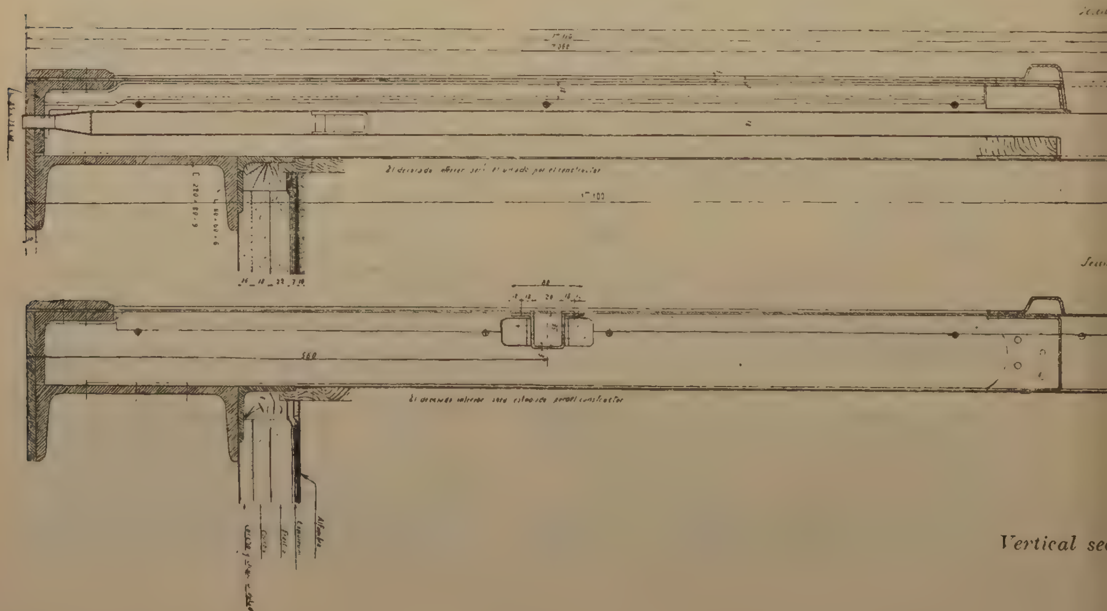

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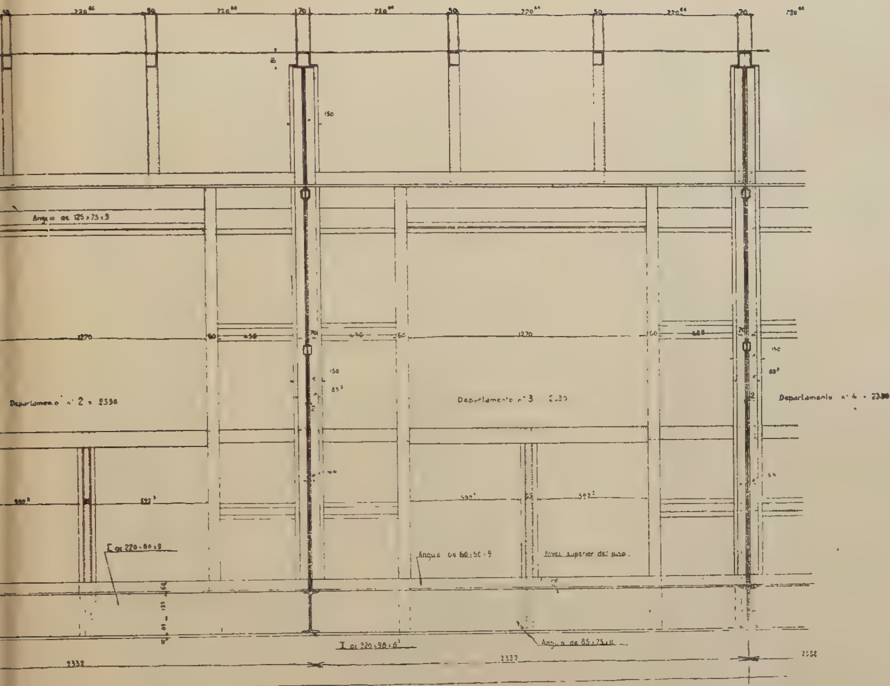

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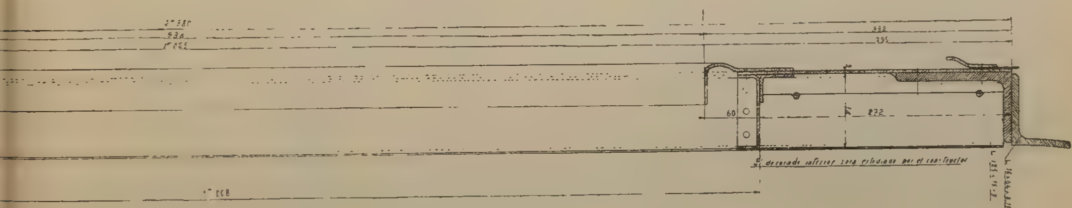

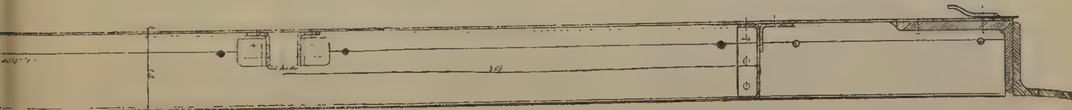

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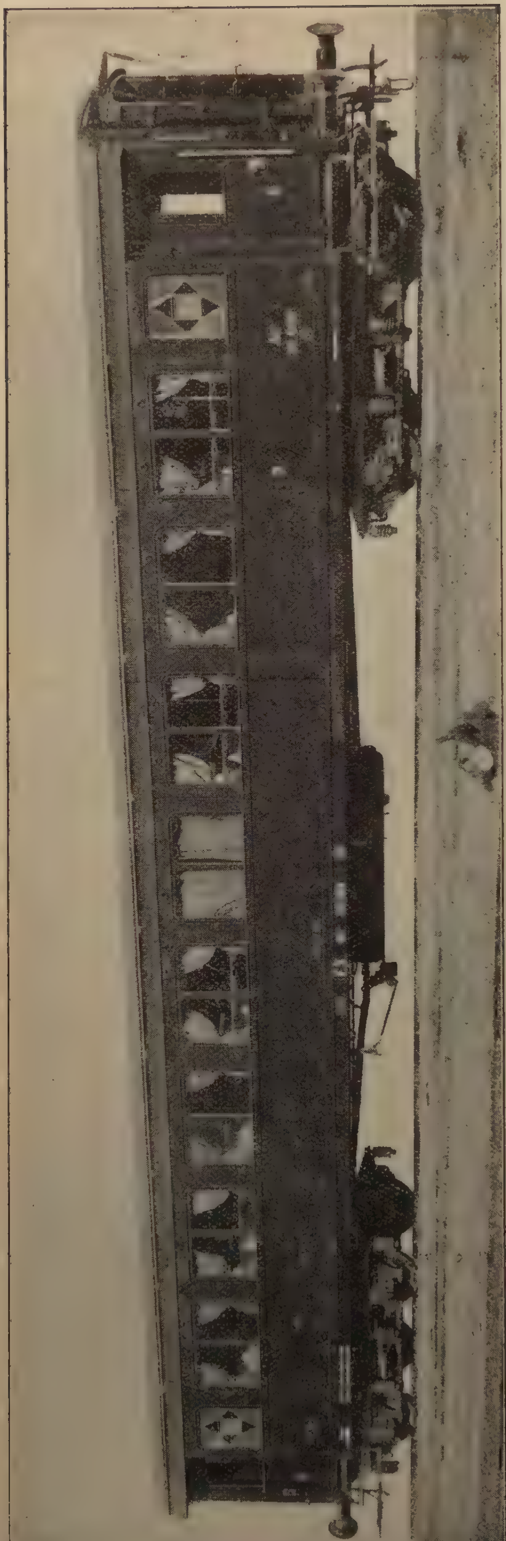


Fig. 6. — Italian State Railways. — Outside view of a coach with counter sunk rivets.

able whilst providing greater safety has only been continued.

The types of steel coaches that are most usually built in the countries dealt with in the present report can be reduced to two: one which uses the sides of the coach as trellis girders of the Vierendeel type formed by the sides, connected by the roof carlines and the cross bearers of the frame, a design which enables the frame to be made lighter, and the other in which a strong frame carries a light body.

It is difficult to give at the present time the preference to one or other of these types, as the advantage of the lower weight of the former, is perhaps counterbalanced by the greater strength of the other to shocks. The use of standard rolled sections for the frame as well as for the pillars, and roof carlines, is usual in most metal coaches. For the latter details the use of bent plates is also usual, and to a less extent pressings.

Cast steel is widely used for connecting together details of the body and of the frame, and in certain instances for the ends of the frames, which latter application in our opinion, is desirable because of the additional strengthening up of the frame, at the cost perhaps, of a slight increase of weight.

Are standard rolled sections, or bent plates to be given the preference when building metal coaches? — On this subject opinions are divided, and depend upon the special circumstances of the industry of the country, of the type of construction, etc.

By using bent plates, it is possible to reduce the weight of the vehicles lightly because the thicknesses of the plates used are much thinner than those of rolled sections; the latter on the other hand can be readily purchased and their greater thickness renders them less liable to deterioration by rusting.

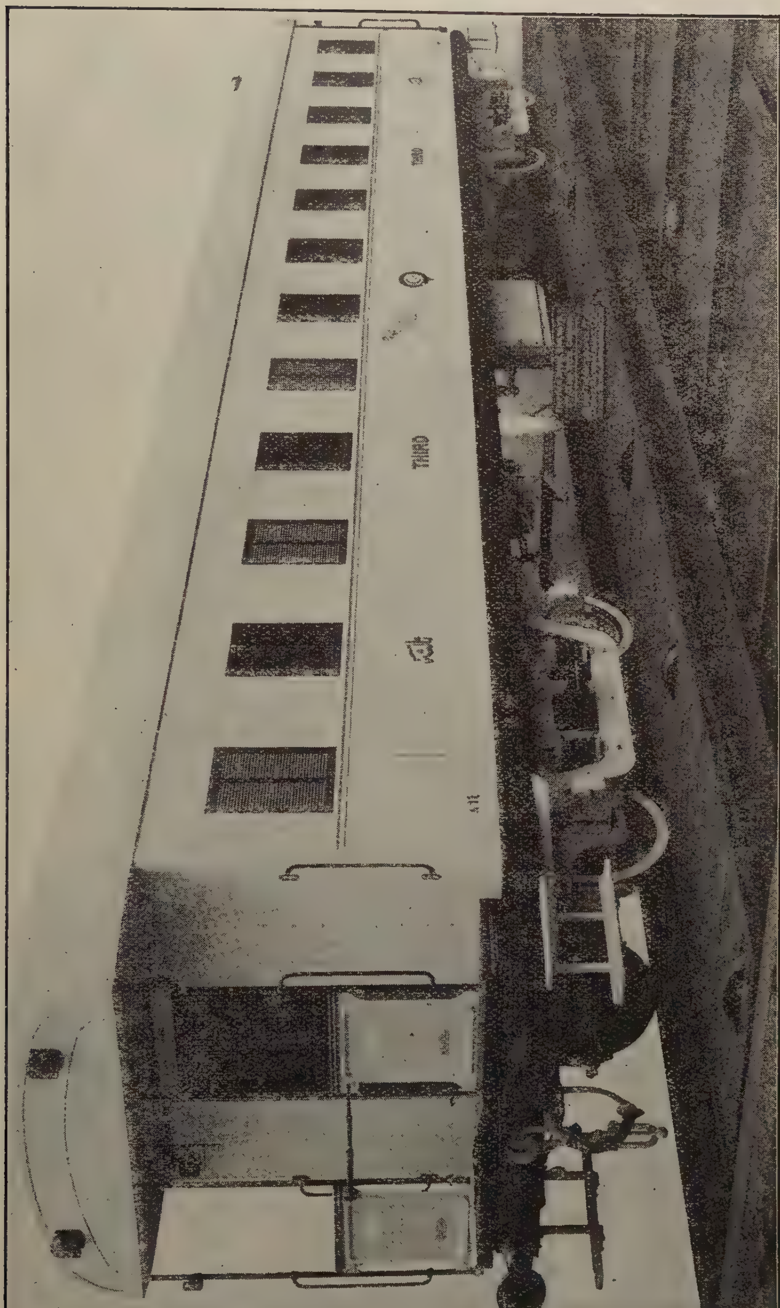


Fig. 7. — Egyptian State Railways. — Outside view of a coach with the rivet heads visible.

Fig. 8. — Interior view of a compartment of a metal coach of the Italian State Railways.

Fig. 9. — Interior view of the corridor of the first class metal coaches. of the Italian State Railways.

Fig. 10. — Interior view of the corridor and toilet compartment of a first class metal coach of the Italian State Railways.

The assembled vehicle is also more rigid than when bent plates are used, the latter being difficult to bend over with a sharp angle.

From the point of view of maintenance, it should be remembered that when details have to be replaced, the Railways would have, in many cases, to equip themselves with special machinery for bending the plates, and such machines being used for this purpose alone, could not be utilized in an economical manner.

As regards pressings, from a constructional point of view we think their use

Fig. 11. — Vehicle No. 10085 of the Italian State Railways after being in collision with a locomotive at Formia on the 7 September 1928.

Fig. 12. — Vehicle No. 10085 of the Italian State Railways after being in collision with a locomotive on the 7 September 1928.

is very desirable, but we consider it to be cheaper only when the number of vehicles of the same type to be built is relatively great.

The interior divisions are usually of wood, but there appears to be a tendency in modern construction to use metal divisions, in order to better cross brace the vehicles and to make them more rigid.

Light alloys are used to a small extent to reduce the weight of metal coaches, but we believe that they can be suppressed if the vehicles are well designed.

Electric welding and electric spot weldding, as well as riveting appear to be the best methods for assembling the parts used in metal coaches; counter sunk rivets appear to give good results especially when used in details of a fair thickness.

Whether counter sunk or round head rivets be used, is a question of taste: some Companies consider the former ought to be used in preference in the case of luxury vehicles.

Wood is being used less and less for the ceilings and floors; the latter are being made of corrugated steel covered with some insulated substance.

Rusting of the sheets, so far has not given any of the Companies using metal coaches in service any anxiety; the use of copper bearing steel as well as painting the plates with red lead, or other suitable paint, appears to give good results.

The usual paints employed are enamels and nitrocellulose . The use of the latter appears to be coming more general, owing to the good results obtained in the tests carried out so far.

The decoration of the inside of the metal coaches is practically the same as that of wooden stock; mahogany, pitch pine, lincrusta, etc., are used as well as marquetry, in rare woods, for the luxury vehicles; for the corridors, similar materials are used; for the vestibules, either teak or enamelled sheets; for certain suburban vehicles the bare plates are painted and for the toilet compartment, enamelled sheets, vitrified enamelled plates, stove enamelled plates, and tiles are used.

Owing to the great conductibility of the metal, metal coaches are more sensible to changes of temperature, and it is necessary to pay particular attention to the insulation by fitting the walls and ceilings with insulating materials such as compressed cork, asbestos, felt, etc.

In the same way the heating and ventilation must be given great attention, and both must be increased; the type of ventilators in general use, do not appear to be adequate in hot countries, and for this reason, even the exterior colour of the vehicles is given attention in order that heat may be the better radiated.

Finally, these vehicles are not difficult to maintain, and in the event of accident, the damages being localised, the cost of repairs are lower.

The use of steel coaches is increasing day by day, owing to the advantages enumerated above. All types, from sleeping cars and saloons down to ordinary suburban vehicles, or tramway stock, whether on bogies or on four wheels, and for all gauges, are being built.

In the case of large heavy bogie vehicles, it appears that the use of monoblock bogies in cast steel with equalising levers is becoming general in place of bogies with rolled steel frames.

We cannot end this report without expressing our hope that in view of the advantages offered by metal coaches those Railways not yet employing them should do so and we consider it is much to be desired, that before long all the great Railway Companies should build all their stock entirely in metal, in place of the vehicles with wooden bodies used up to the present.

Madrid, February 1929.

ALL METAL COACHES

AND

COACHES WITH WOODEN BODIES.

All me

COUNTRY.	RAILWAY.	Class and vehicle number.	Service in which used.	Gauge of lines — Width.	Gauge of lines — Standard European.	Bogie.
1	2	3	4	5	6	7
Egypt	State Railways.	...	Fast and express.	...	...	Yes.
Spain	North of Spain.	AAFHV. 1001	Fast.	1.674m.	...	Yes.
do.	do.	W.R. 1.	Suburban.	do.	...	Yes.
Holland	Netherlands Railways.	ARC. 850.	Fast suburban on electrified lines.	...	Yes.	Yes.
do.	do.	AB. 7201.	International trains.	...	Yes.	Yes.
Italy	State Railways.	...	Fast and express.	...	Yes.	Yes.
do.	North of Milan.	...	Suburban.	...	Yes.	Yes.
Poland	State Railways.	...	Fast.	. .	...	Yes.
Portugal	Portuguese Railways.	...	Various.	1.674m.	. .	Yes.
do.	do.	...	do.	do.	...	...
Rumania	State Railways.	...	Fast and express.	...	Yes.	Yes.
do.	do.	...	do.	...	Yes.	Yes.
do.	do.	...	do.	...	Yes.	Yes.
Switzerland	Federal Railways.	C^{40} 8724.	Express.	...	Yes.	Yes.
do.	do.	B^{40} 3951.	do.	...	Yes.	Yes.
Czecho-Slovakia . .	State Railways.	...	Fast.	...	Yes.	Yes.
Yugoslavia	State Railways.	A. B^{40}.	...	...	Yes.	Yes.
International Sleeping Car Company		...	Express.	1.674m.	Yes.	Yes.

Na

Spain	Estella to Vitoria.	. .	...	1 metre	...	Yes.
do.	Zumàrraga to Zumaya (Urola).	...	Various.	1 metre	...	Yes.
Switzerland	Rhætian Railway.	A.B^{40}.	...	1 metre	...	Yes.

ches.

	COACHES.						Year built.	Length (in metres).		
x-led.	With end entrances.	With multiple entrances.	With large side entrances.	Corridor.	Semi-corridor.	Non-corridor.		Over buffers.	Over body.	Inside of body.
	10	11	12	13	14	15	16	17	18	19
.	Yes.	...	...	Yes.	...	...	...	21.063	19.964	19.850
.	Yes.	...	...	Yes.	...	...	1929	20.300	19.000	18.900
.	Yes.	...	Yes.	Yes.	...	...	1928	21.160	20.550	20 424
.	Yes.	At the ends.	...	Yes.	...	...	1924 1927	19.800	18.500	18.370
.	Yes.	...	...	Yes.	...	...	1928	21.800	20.500	20.372
.	Yes.	...	...	Yes.	...	...	1921 1928	21.040	19.700	19.594
.	...	..	Yes.	Yes.	..	...	...	20.600	19.400	...
.	Yes.	...	...	Yes.	...	...	1928	22.020	20.720	20.580
.	Yes.	...	..	Yes.	...	...	...	...	18.300	...
.	...	Side.	...	...	Yes.	...	...	...	13 595	13.440
.	Yes.	...	...	Yes.	...	...	1927 1928	21.000	19.700	19.500
.	Yes.	...	...	Yes.	...	...	1924	20.440	19.140	19.004
.	Yes.	...	...	Yes.	...	...	1924	20.440	19.140	19.004
.	Yes.	...	...	Yes.	...	...	1928 1929	20.050	18.750	16.596
.	Yes.	...	...	Yes.	...	...	1928	20 400	19.100	16.946
.	Yes.	...	...	Yes.	...	...	1925	22.680	21 520	21 420
.	Yes.	...	...	Yes.	...	...	1923	19.650	18 350	18.220
.	Yes.	...	...	Yes.	...	...	1920 1928	23.450	22.200	20.500

ge.

.	Yes.	...	...	Yes.	...	...	1928	14.040	13 060	...
.	Yes.	...	...	No.	Central.	...	1928	15.900	15 000	14.920
.	Yes.	...	...	Yes.	...	...	1929	16.400	15 500	13.600

All m

COUNTRY.	RAILWAY.	Overall height above rail level (in metres).	Interior width at the waist rail (in metres).	Inside height on the center line (in metres).	Floor area (square metres).	Tare weight, tanks empty (in kilogrammes).	Bogies. TYPE.
1	2	20	21	22	23	24	25
Egypt	State Railways.	4.318	2.660	2.635	49.31	43000	...
Spain	North of Spain.	4.020	2.928	2.465	57.40	43000	Cast steel monoblock.
do.	do.	3.675	2.924	2.337	60.00	46500	do.
Holland	Netherlands Railways.	3.735	2.834	2.400	51.00	39000	German.
do.	do.	3.940	2.680	2.558	54 00	51000	American.
Italy	State Railways.	3.825	2.730	2.494	52 00	41000 42500	Rolled sections and pressings.
do.	North of Milan.	...	...	...	...	36000	American with frame made of rolled sections.
Poland	State Railways.	4 000	2.730	2.644	57.82	46000	American.
Portugal	Portuguese Railways.	4 084	3 011	2 600	56.85	...	. .
do.	do.	...	2.985	2.513	42.70	...	...
Rumania	State Railways.	3.825	2.698	2.605	54.42	42500	Pressed steel.
do.	do.	3.987	2.759	2.733	53 93	41100	do.
do.	do.	3.987	2.759	2.733	53.93	41100	do.
Switzerland	Federal Railways.	3.860	2 755	2.480	49.90	38000	S. W. S.
do.	do.	3.860	2.755	2.485	50.80	41000	S. W. S.
Czecho-Slovakia . .	State Railways.	3 900	2.695	2.555	54.20	41500	...
Yugoslavia	State Railways.	4.025	2 790	2.580	54.20	42500	. .
International Sleeping Car Company.		4.000	2.854	2.825	54.55	48000 55000	Cast steel monoblock.
							Na
Spain	Estella to Vitoria.	3.470	2 330	...	32 00	27200	Rolled sections.
do.	Zumárraga to Zumaya (Urola).	3.500	2 196	2.069	34.80	17400	do.
Switzerland	Rhætian Railway.	3.450	2.470	2.500	33.59	19500	...

ches *(Continued)*.

	Number of places.					Weight (in kilogrammes).			Number of carriages of the same type.		VARIOUS.
	Sitting.		Standing.								
s.	2nd class.	3rd class.	1st class.	2nd classe.	3rd class.	Per linear me re (excluding buffers).	Per passenger.	Per square metre of floor surface.	Built.	To be built before 1930.	
	28	29	30	31	32	33	34	35	36	37	38
	...	..	...	...	...	2155	956 (1st class).	872	169	...	Possesses 82 third class carriages without brake with 107 places and 50 with brake fitted.
	...	...	..	...	...	2263	1194	749	...	20	B. B. electric lighting. Westinghouse heating.
	...	104	...	...	32	2263	342	775	14	14	Electric lighting and heating.
	...	88	...	....	24	2110	348	765	34	...	...
	36	...	...	...	...	2488	1159	945	9	..	...
	64	80	...	..	...	2050	960-630-500	775	800	500	...
	Per coach.										
	...	102	...	...	...	1855	353	..	...	...	...
	33	...	...	...	...	2220	-1122	795	10	80	...
	...	...	...	...	...	...	..	...	...	...	Inside lining in wood.
	..	...	...	...	...	...	...	...	...	...	do.
	64	...	...	...	...	2160	664	780	...	...	...
	1st and 2nd. cl	...	...	...	...	2140	822	764	...	...	...
	...	...	...	...	...	2140	980	764	...	..	...
	...	80	..	...	...	2027	475	762	...	14	Steam heating. Electric lighting and heating.
	46	...	...	...	...	2146	892	807	6	4	do.
	...	88	...	...	..	1930	473	768	...	...	...
	20	...	...	...	...	2315	1184	783	...	...	...
	...	...	..	...	...	2047 2345	...	880 1008	626	324	...

ge *(Continued)*.

	...	32	...	...	...	2082	618	850	...	...	...
	One class. 48 sitting.		...	...	...	1160	362	500	...	...	...
	30	...	...	...	...	1257	464	542	...	...	Electric heating.

Coaches w

COUNTRY.	RAILWAY.	Class and vehicle number.	Service in which used.	Gauge of lines		Bogie.
				Width.	Standard European.	
1	2	3	4	5	6	7
Egypt	State Railways.	...	Suburban.	...	...	Yes.
Spain	North of Spain.	AA^{fhv} 27-30.	Fast.	1.674m.	...	Yes.
do.	do.	AA^{fhv} 685-696.	Express and mail.	do.	...	Yes.
do.	do.	CC^{fhv} 201-220.	Suburban.	do.	...	Yes.
do.	Central Aragon.	...	...	do.	..	...
do.	do.	...	...	do.	...	...
Finland	State Railways.	...	Suburban.	...	...	...
do.	do.	...	Long runs.	...	...	Yes.
Holland	Netherlands Railways.	A.B. 7509	International trains.	...	Yes.	Yes.
Italy	State Railways.	...	Various.	...	Yes.	Yes.
Norway	do.	...	Suburban.	...	Yes.	Yes.
do.	do.	...	Long runs.	...	Yes.	Yes.
do.	do.	...	Fast.	...	Yes.	Yes.
Poland	do.	...	do.	...	...	Yes.
Rumania	do.	...	do.	...	Yes.	Yes.
Switzerland	Federal Railways.	C^{lo} 8712-23.	Express and stopping.	...	Yes.	Yes.
Czecho-Slovakia	State Railways.	...	Fast.	...	Yes.	Yes.
Yugoslavia	do.	A.B °.	...	...	Yes.	Yes.

Na

Switzerland	Rhætian Railway.	$A.B^{4}$ 201-206.	Various.	1 metre	...	Yes.

den bodies.

	COACHES.						Year built.	Length (in metres).		
d.	With end entrances.	With multiple entrances.	With large side entrances.	Corridor.	Semi-corridor.	Non-corridor.		Over buffers.	Over body.	Inside of body.
	10	11	12	13	14	15	16	17	18	19
	Yes.	...	...	Yes.	...	...	...	21.063	19.963	19.926
	Yes.	...	...	Yes.	...	...	1926	18.630	17.390	17.290
	Yes.	...	...	Yes.	...	...	1928	20.000	18.700	18.600
	Yes.	...	...	Yes.	...	...	1927	20.000	16.120	16.000
	Yes.	...	...	Yes.	...	...	1898	14.400	13 100	...
	Yes.	...	...	Yes.	...	...	1898	14.400	13.100	...
	Yes.	...	...	Yes.	...	...	Recently.	14.280	13.100	13.200
	Yes.	..	...	Yes.	...	...	do.	20.800	19.620	19.540
	Yes.	...	...	Yes.	...	...	1920	19.380	18.080	17.850
	Yes.	Yes.	...	Yes.	...	...	1910 1920	18.480	17.200	17.080
	Yes.	...	Yes.	Yes.	...	...	...	18.800	17.500	...
	Yes.	...	...	Yes.	...	...	...	19.500	18 200	...
	Yes.	...	...	Yes.	...	...	...	19.800	18.500	...
	Yes.	...	...	Yes.	...	...	1925	19.950	18.670	18.530
	Yes.	...	...	Yes.	...	...	1923 1924	19.750	18.470	18.400
	Yes.	...	...	Yes.	...	...	1927 1928	19.860	18.560	16.600
	Yes.	...	...	Yes.	...	...	1925	22.680	21.520	21.420
	Yes.	...	...	Yes.	...	...	1923 1927	19.600	18.300	18.220
e.										
	Yes.	...	...	Yes.	...	...	1913	16.000	15.100	13.600

Coaches w

COUNTRY.	RAILWAY.	Overall height above rail level (in metres).	Interior width at the waist rail (in metres).	Inside height on the center line (in metres).	Floor area (square metres).	Tare weight, tanks empty (in kilogrammes).	Bogies. TYPE.
1	2	20	21	22	23	24	25
Egypt	State Railways.	4.318	2.616	2.692	49.62	44000	...
Spain	North of Spain.	4.080	2.964	2.465	52.10	37700	Rolled sections and pressings.
do.	do.	4.080	2.990	2.465	58.00	40100	Monoblock steel.
do.	do.	4.080	2.992	2 465	56.80	38250	do.
do.	Central Aragon.	3.900	3.200	...	41 92	18800	...
do.	do.	3 900	3.200	...	41.92	17250	...
Finland	State Railways.	4.147	2.970	2.765	35.50	17450	...
do.	do.	4.155	2.928	2.765	54.80	35800	4-wheeled.
Holland	Netherlands Railways.	3.995	2.860	2.600	50.00	39000	German.
Italy	State Railways.	3.800	2.700	2.420	43.70	30000 32000	Rolled sections and pressings.
Norway	do.	4.020	2.940	2.645	47.00	...	Rolled sections.
do.	do.	4.010	2.940	...	55.09	...	do.
do.	do.	4.010	2.940	...	56.02	....	do.
Poland	do.	4.004	2.690	2.606	53.18	42000	American.
Rumania	do.	3.840	2.740	2.500	49.23	37500	Pressed steel.
Switzerland	Federal Railways.	3 850	2.760	2.475	49.50	37000	American.
Czecho-Slovakia . .	State Railways.	3.900	2.695	2.555	54.20	39000	4-wheeled.
Yugoslavia	do.	4.052	2.750	2.635	54.35	37500	...
							Na
Switzerland	Rhætian Railway.	3.420	2.470	2.495	33.592	16920	...

den bodies (*Continued*).

Number of places.					Weight (in kilogrammes).			Number of carriages of the same type.		VARIOUS.
Sitting.		Standing.								
2nd class.	3rd class.	1st class.	2nd classe.	3rd class.	Per linear me re (excluding buffers).	Per passenger.	Per square metre of floor surface.	Built.	To be built before 1930.	
28	29	30	31	32	33	34	35	36	37	38
72	114	...	...	...	2205	978	886	...	...	...
Per coach.										
...	...	. .	...	...	2167	1st. cl. 1047	723	4	...	Exterior lined out in teak. B. B. electric lighting. Westinghouse steam heating.
...	...	...	...	...	2144	872	707	96	15	do.
...	100	..	..	24	2045	308	673	120	...	do.
30	...	...	...	. .	1430	376	450	...	...	...
...	93	...	...	...	1310	183	411	...	...	...
...	61	...	...	30	1340	286	492	...	...	...
30	...	...	20	...	1825	945	654	...	...	...
32	...	...	...	...	2150	780	780	8	...	...
60	80	...	...	...	1800	800 500 380	700	...	...	...
Per coach.										
...	76	...	...	...	1600	290	630	...	...	...
...	64	...	...	...	...	...	...	...	...	...
30	Employed as a sleeping car.		10 1st.	20 2nd.	...	...	...	...	...	...
24	...	...	...	. .	2249	1235	789	...	...	...
...	...	...	...	...	2030	1042	763	...	...	...
...	80	...	...	...	1994	463	747	12	...	Electric heating and lighting.
...	88	...	...	...	1870	450	729	...	...	...
32	...	...	...	...	2050	850	690	...	...	...

e (*Continued*).

30	...	...	...	...	1120	403	503	6	...	...

[656. 25]

REPORT No. 1

(**America**, **British Empire**, **China and Japan**)

ON THE QUESTION OF SIGNALLING OF LINES FOR FAST TRAFFIC AND IN MAIN STATIONS. DAYLIGHT SIGNALS. AUTOMATIC BLOCK SYSTEM (SUBJECT XI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION,

By G. H. DRYDEN,

SIGNAL ENGINEER, BALTIMORE AND OHIO RAILROAD COMPANY.)

Figs. 1 to 53, pp. 1806 to 1863.

The questionnaire on « Signaling of lines for fast traffic and in main stations, Daylight signals and Automatic block system » was sent out to the various Railways in Canada, South America, the British Empire, China and Japan, and detailed replies were received from 38 Railways, the Officials of which I wish to thank for their time and efforts in supplying the desired information, and regret that in view of the available space it has been necessary to brief the report and leave out a certain amount of the interesting information which they have so kindly furnished.

Your reporter will not enter into details connected with the systems adopted or discuss the principles of signaling in the United States and Great Britain as this subject was so ably stated by Mr. W. H. Elliot, Signal Engineer, New York Central Railroad, in the *Bulletin of the Railway Congress* for November 1924, page 907, and by the late Mr. Thorrowgood, Signal and Telegraph Superintendent, Southern Railway (Gt. Britain), in the *Bulletin* for January 1925, page 79. It is the purpose, rather, to state the present practice in the more recent signaling installations with particular reference to daylight signaling and the present tendency in the various countries, showing the extent and type of signaling in service and finally a summary discussion of the practices in the different countries.

United States and Canada.

Signaling of lines for fast traffic.

In reporting on the subject of signaling of lines for fast traffic it is desirable to state that the standards and practices herein described are those of the large railroad systems of the United States and Canada upon which there are fast and heavy traffic movements. The art of signaling on these railroads has been developed through the work of the Signal Section of the American Railway Association to whom proper credit is acknowledged for some of the subject matter herein presented.

Of the 200 000 miles of road in the United States upon which passenger lines are operated, about 830 miles are protected with the controlled manual block system; 59 000 miles with the manual block system and 58 000 miles with the automatic block system, there having

Fig. 1. — Color position light signals installed in automatic block territory on the Baltimore & Ohio Railraod.

been a very large increase in the mileage of automatic block signals in the past five years. While the manual block system is generally used on light traffic lines, those railroad systems having fast and heavy traffic movements are not only equipped with automatic block signals, interlocking signals, and reverse traffic signals for operating trains in either direction by signal indications without train orders, but a most important factor in railroad operation in the United States has been the increased protection secured against accidents by the installation of automatic train control devices. Fifty railroads operate some or all of their trains under its protection, 20 000 miles of equipped track protect train movements into thirty five states, and over nine thousand equipped locomotives and electric cars are now operating over these tracks so that 14 % of all the locomotives operating in the United States, and nearly 7 % of the track mileage are now equipped for automatic train control.

While in England the driver rides on the left side of the engine and the signal mast is placed on the left side of the track, in North America the engineman occupies the right side of the cab, the signal mast is placed on the right side of the track, and the signal operates in the right hand quadrant where it can be observed by an approaching train. Where signals cannot be located at clearance point to the right of the governed track, they are either located on bracket or cantilever masts or on signal bridges.

While in the early years of North American signaling, the signals were of

Fig. 2. — Color light automatic block signals on the Delaware, Lackawanna & Western Railroad.

Fig. 3. — Position light signals for high speed traffic on the Pennsylvania Railroad.

Fig. 4. — Automatic block signals of the searchlight color light type on the Canadian Pacific Railway.

the semaphore type, the general tendency in recent years has been the gradual adoption of light signals until now the majority of all new signaling for automatic signal and interlocking purposes, is of the color light, position light or color position light types. Of the 13 165 miles of road of fast traffic lines equipped with light signals, 10 481 miles are of the color light type, 2 227 miles are of the position light type and 457 miles are of the color position light type, 9 000 miles of road of automatic block signals of the light type having been installed in the past three years.

Automatic signal blocks are generally spaced a minimum of braking distance apart, usually about 4 000 to 5 000 feet, with an average length of one mile and a maximum length of one and one half to two miles. Various factors, such as braking power, type of freight or passenger traffic, grades, and curves, determine the block spacing although in some cases where the trains are spaced on a time basis rather than a mileage basis, the blocks will be of unequal length depending upon local operating conditions. In high speed suburban territory adjacent to large cities like New York, Philadelphia, and Chicago, where trains must necessarily be spaced very near together due to train departures from a terminal station being made at the same instant, it is often found desirable to space the signals less than braking distance apart, 1 000 to 1 700 feet, and in such cases a three block indication scheme has been adopted rather than the usual two block indication ordinarily installed in automatic block signal territory.

The uniform system of signaling used in North American practice is that prescribed by the Standard Code of the American Railway Association and shown in figures 5 to 8. It will be noted that the equivalent names, aspects and indications are given for either semaphore, color light, position light or color-position light signals as used in manual block, automatic block and interlocking practice. An automatic signal giving two block indications provides three indications; « Stop then Proceed as per Rule 509-B » Code Rule 291, for an occupied block; « Prepare to stop at next signal ». Train exceeding medium speed must at once reduce to that speed, Code Rule 285, for the second signal in the rear of an occupied block; and « Proceed », Code Rule 281, for the third signal in the rear of an occupied block. Where three block indications are given the following indications are provided; « Stop then Proceed as per Rule 509-B » for an occupied block; « Prepare to stop at next signal. Train exceeding medium speed must at once reduce to that speed », for the second signal in the rear of an occupied block; « Approach next signal at not exceeding medium speed », Code Rule 282, for the third signal in the rear of an occupied block; and « Proceed » for the fourth signal in the rear of an occupied block. Figure 9 shows the aspects and indications for the two and three block automatic signal system. Ordinarily an automatic block signal is distinguished from other signals by a number plate or a marker light, or both.

In order to save stops to tonnage trains on grades, a number of roads have eliminated the « Stop then Proceed » automatic block signal at the entrance to an occupied block by substituting a restrictive automatic block signal indicating « Proceed at restricted speed ». Such signals are of great benefit on grades where the stopping of tonnage trains is

APPLICATION OF SIGNALS.

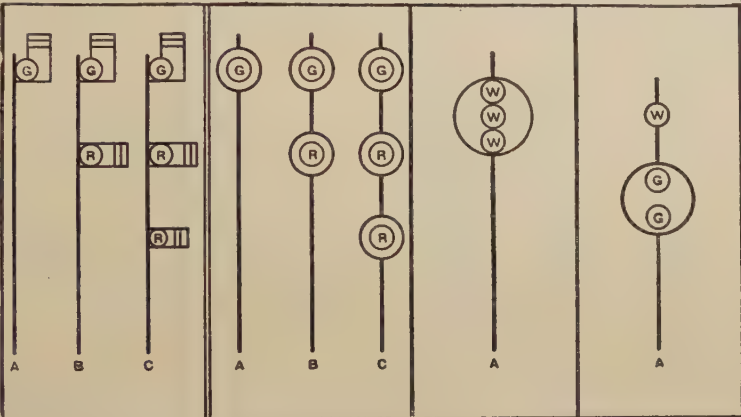
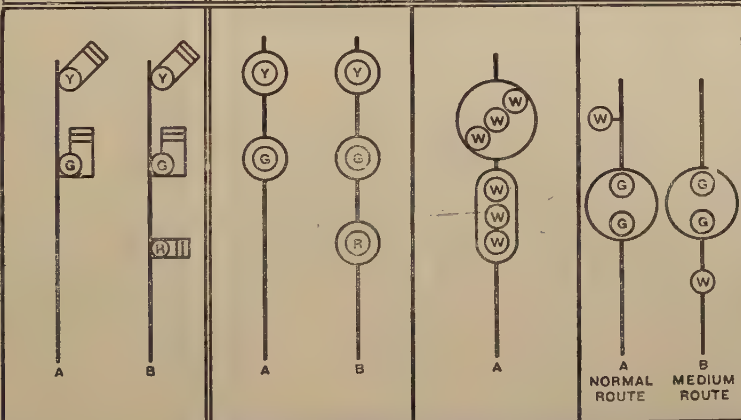
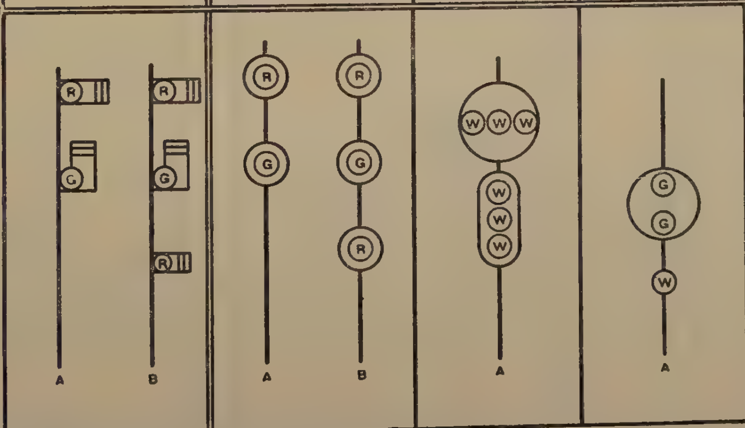
A.R.A. CODE RULE.	ASPECTS. A.R.A. TYPICAL. SEMAPHORE.	ASPECTS. EQUIVALENT. COLOR LIGHT.	POSITION LIGHT.	COLOR POS. LIGHT.	REMARKS.
281					INDICATION. — Proceed. NAME. — Clear. APPLICATION. — At entrance of normal speed route or block, to govern train movements at normal speed.
282					INDICATION. — Approach next signal at not exceeding medium speed. NAME. — Approach-Medium. APPLICATION. — At entrance of normal speed route or block, to govern the approach to clear medium, approach, medium approach, or approach medium signals.
283					INDICATION. — Proceed at not exceeding medium speed. NAME. — Clear-Medium. APPLICATION. — At entrance of medium speed route or block, to govern train movements at not exceeding medium speed.

Fig. 5.

APPLICATION OF SIGNALS.

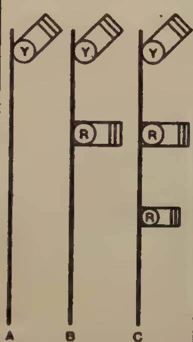
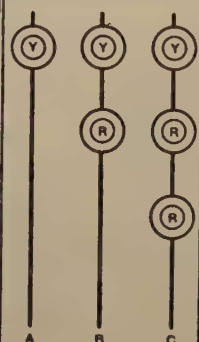
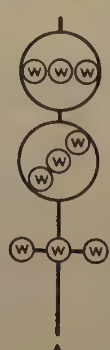
A. R. A. CODE RULE.	ASPECTS.				
	A. R. A. TYPICAL.	EQUIVALENT.			
	SEMAPHORE.	COLOR LIGHT.	POSITION LIGHT.	COLOR POS. LIGHT.	REMARKS.
284					INDICATION. — Approach next signal at not exceeding slow speed. NAME. — Approach-Slow. APPLICATION. — At entrance of normal speed route or block, to govern the approach to clear slow, slow approach, or restricting signals.
285					INDICATION. — Prepare to stop at next signal. Train exceeding medium speed must at once reduce to that speed. NAME. — Approach. APPLICATION. — At entrance of normal speed route or block, to govern the approach to clear slow, slow approach, permissive, restricting, stop and proceed, or stop signals; red switch lamp and end of signaled territory.
286					INDICATION. — Proceed at not exceeding medium speed prepared to stop at next signal. NAME .— Medium-Approach. APPLICATION. — At entrance of medium speed route or block, to govern the approach to clear slow, slow approach, permissive, restricting, stop and proceed, or stop signals and end of signaled territory.

Fig. 6.

APPLICATION OF SIGNALS.

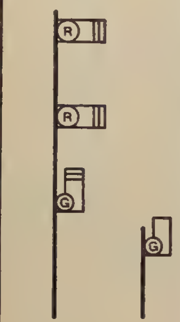
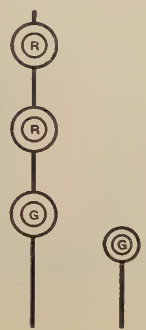
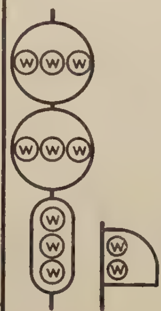
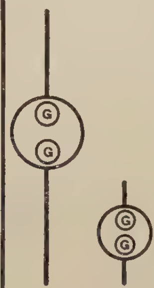
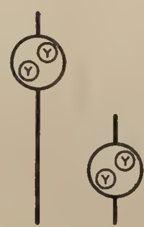
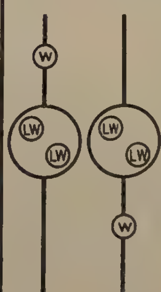
A.R.A. CODE RULE.	ASPECTS.				
	A.R.A. TYPICAL.	EQUIVALENT.			
	SEMAPHORE.	COLOR LIGHT.	POSITION LIGHT.	COLOR POS. LIGHT.	REMARKS.
287					INDICATION. — Proceed at not exceeding slow speed. NAME. — Clear-Slow. APPLICATION. — At entrance of slow speed route or block, to govern train movements at slow speed.
288					INDICATION. — Proceed at not exceeding slow speed prepared to stop at next signal. NAME. — Slow-Approach. APPLICATION. — At entrance of slow speed route or block, to govern the approach to permissive, restricting, stop and proceed, or stop signals.
289	 (SEE NOTE)	 (SEE NOTE 1-2-4)	 (SEE NOTE 1-2-4)		INDICATION. — Block occupied, proceed prepared to stop short of train ahead. NAME. — Permissive. APPLICATION. — At entrance of a manual block to govern trains entering and using that block. Note: Designate by: 1-Letter Plate, or 2-Marker Light, or 3-Shape of Arm, or 4-Combination of these distinguishing features.

Fig. 7.

APPLICATION OF SIGNALS.

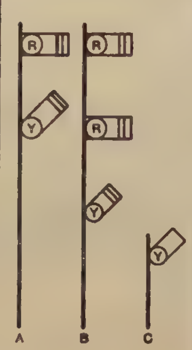
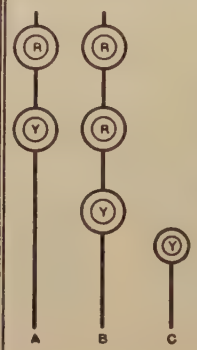
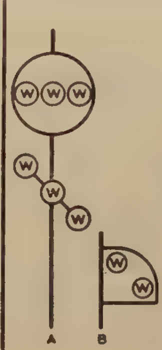
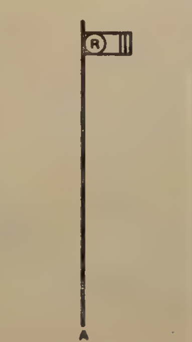
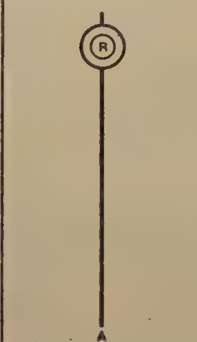
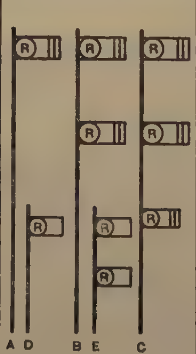
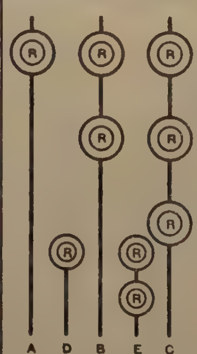
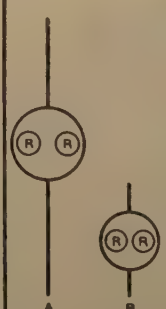
A.R.A. CODE RULE.	ASPECTS. A.R.A. TYPICAL. SEMAPHORE.	EQUIVALENT. COLOR LIGHT.	POSITION LIGHT.	COLOR POS. LIGHT.	REMARKS.
290					INDICATION. — Proceed at restricted speed. NAME. — Restricting. APPLICATION. — At entrance of normal speed, medium speed, or slow speed route or block, to permit trains to proceed prepared to stop short of train, obstruction, or anything that may require the speed of the train to be reduced.
291	 (SEE NOTE)	 (SEE NOTE 1-2-4)	 (SEE NOTE 1-2-4)	 A NORMAL ROUTE — B SLOW OR MEDIUM ROUTE	INDICATION. — Stop; then proceed in accordance with Rule 509-B. NAME. — Stop and Proceed. APPLICATION. — At entrance of a route or an automatic block requiring trains to stop and after stopping, permitting them on two or more tracks to proceed at restricted speed and on single track in accordance with the rules. Note: Designate by 1-Number Plate, or 2-Marker Light, or 3-Pointed Blade, or 4-Combination of these distinguishing features.
292					INDICATION. — Stop. NAME. — Stop. APPLICATION. — At entrance of a route or block requiring trains to stop until authorized to proceed by train order, clearance card, more favorable indication than stop, or in accordance with the rules.

Fig. 8.

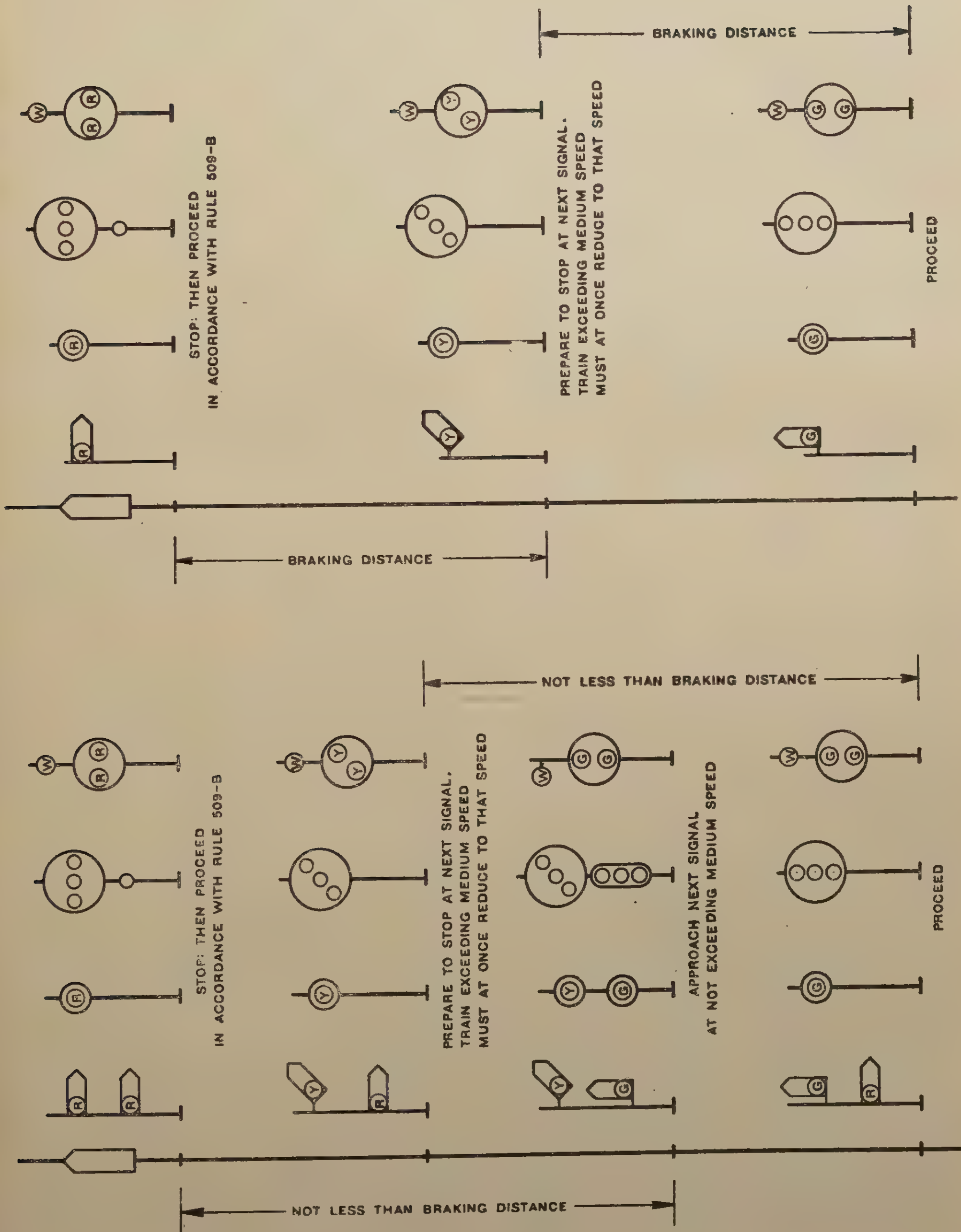

BRAKING DISTANCE
STOP: THEN PROCEED
IN ACCORDANCE WITH RULE 509-B
PREPARE TO STOP AT NEXT SIGNAL.
TRAIN EXCEEDING MEDIUM SPEED
MUST AT ONCE REDUCE TO THAT SPEED
PROCEED
BRAKING DISTANCE
NOT LESS THAN BRAKING DISTANCE
STOP: THEN PROCEED
IN ACCORDANCE WITH RULE 509-B
PREPARE TO STOP AT NEXT SIGNAL.
TRAIN EXCEEDING MEDIUM SPEED
MUST AT ONCE REDUCE TO THAT SPEED
APPROACH NEXT SIGNAL
AT NOT EXCEEDING MEDIUM SPEED
PROCEED
NOT LESS THAN BRAKING DISTANCE

Fig. 9.

liable to cause delays due to trains pulling apart. The percent of grade determining the use of such signals varies on the different roads, but a grade of 0.3 to 0.5 % is a minimum except where an automatic speed control system is used when occupied blocks may all be governed by restrictive signals even on level track. The type of grade signal varies on the different roads but it may be an automatic signal with a special number plate with the letter « G » for Grade Signal; « P » for Permissive Signal, or the restrictive signal indication provided by the Sandard Code Rule 290, modified to suit the tonnage rating or special instructions issued by each road.

On account of the availability of an alternating current power supply at the majority of automatic and interlocking light signals, it is the general practice to continuously light the signals although in some cases approach lighting, i. e., signals automatically lighted on approach of trains, is used particularly on automatic block signals. Where a power supply is not available, necessitating the use of primary battery, it is the general practice to use approach lighting.

The power for automatic block and interlocking signals is usually obtained from a commercial or from a railroad source of supply, or from both, using one source as an emergency supply. Generally this power is received at a voltage of 110, 220, 440, 2 300, or 4 400 volts, single or three phase, 60 cycles, although in special cases 25 and 50 cycle power is used while 100 cycle power is coming into use on coder train control and cab signal installations. For local circuits, 110 volts is generally used around interlocking plants but where power is transmitted from a plant into automatic signal territory a voltage of 220, 440, 2 300, 4 400, 6 600 or 11 000 is adopted, depending upon the length of transmission line and the operated load. While single phase transmission is generally used, some three phase signal lines have been installed. In recent years considerable automatic block signaling has been installed with the signals normally lighted from an alternating current power line, usually 440 volts, and in case of a power failure, from a storage battery which is normally charged by a rectifier from the power line. In these installations 8 or 10 volt direct current is used for relay controls, the power being supplied from the storage battery which acts a reserve source for the signal lights. The usual step-down and step-up transformers, protective and cut-out devices, are installed and sectionalizing switches are located in the power lines at stations or towers for localizing trouble or for work on the power lines.

The type of track circuit used in automatic block signaling and at main stations is determined by local conditions as roads equipped for electric traction must use alternating current track circuits. Roads adopting the continuous type of automatic train control have generally adopted alternating current track circuits, however, where none of these conditions are a factor, the usual track circuit is of the direct current type operated from one cell of storage battery or from two or more cells of primary battery. The track circuit lengths vary on account of the different track layouts in main stations but are usually of short length, from 200 to 1 000 feet, while in automatic block signaling the average length is from 2 600 to 4 000 feet. The majority of all track circuits are of the neutral type although a few roads use polar track circuits as standard practice.

In electric traction territory the propulsion bonding is used for the signal track circuits, but on the usual signal track circuits the practice has been to use two No. 8 BWG iron or No. 6 BSG copper or copperweld wires bonded with channel pins at each point. In recent years the tendency has been towards a more substantial type of bonding of either a gas welded short copper bond or a heavy stranded iron or copper or combined iron and copper wire construction bonded around each joint. While a No. 9 or No. 6 copper wire track connection has been usually installed in the past, many roads are now adopting a heavy stranded track wire connection between the rail and the insulated track wire leading to the track relay.

It is the general practice to interlock the main track switches for the protection of crossover and switching movements at main terminals, yards, and congested points along the line, but at other intermediate points the switches are non-interlocked, being hand operated by the local train crews. However, these switches are interconnected with the signal system so that a misplaced switch will hold the governing signal in its most restrictive position. On many high speed lines in congested territory, every switch is interlocked, except in case of a hand operated switch at an unimportant location an electric lock under control of the operator controls movements on to the main line. Some roads are adopting the practice of securing additional protection at non-interlocked switches by the addition of a special locking mechanism which ensures that the switch will not open if the operating rod is broken, thus securing practically equal locking protection on hand throw switches as at interlocking switches.

Four types of line wires are used for signal control circuits on open line construction; No. 8 or No. 9 galvanized iron, No. 4, No. 6, No. 8 and No. 10 copper, No. 9, No. 10 and No. 12 copperweld, and No. 4, No. 6 and No. 9 aluminum steel reinforced. While a few roads use bare line wires, the majority use a double or triple weatherproof braid to guard against signal failures caused by crosses and grounds. Ordinarily open line construction is only used when the number of wires is 10 or less as in the case of a remotely controlled switch, or at an interlocking plant, cable construction is installed. Open line wires are supported on glass or porcelain insulators mounted on a wood crossarm. Voltages up to 550 volts and 1 600 watt load are used on the same cross-arm with the 10 volt or 110 volt signal control circuits. While some roads build a separate pole line for the signal wires and cables; it is the general practice to use the joint telegraph and railroad pole line for the signal circuits.

Wires attached to relays, signals, interlocking machines and other signal devices are of soft drawn copper covered with an insulation of rubber or other insulating material, and with a braid or tape and braid over all. The sizes of wires vary but No. 16 is sometimes used for relay leads and tower wiring, No. 9, No. 12 and No. 14 for controls, while No. 9 and No. 6 are used for track connections, battery and common mains and for long signal controls. Signal wires and cables may be run in wooden trunking near the surface of the ground or buried in the ground, in fibre or tile duct lines in the ground, or in concrete trunking mounted on top of the ground. In recent years a steel tape and often a lead protection cover has been placed ovec signal wires

Fig. 10. — Hand operated switch mechanism for main line protection.

Fig. 11. — Underground cable and rail connection joined in head of improved « bootleg ».

and cables after which they are run in the ground without trunking. Where aerial construction is used, the insulated wires are usually run in multiple conductor cables supported by cable clips on messenger wires. While the size of the wire in the cable will vary with the type of service, sizes less than No. 12 or No. 14 are seldom used. Aerial cables are usually installed with only a braid cover but in some cases a lead cover is used, and even a steel tape cover has been placed in aerial runs where protection against gun shots and sleet storms was desired.

The relays in interlocking stations are usually housed in steel cases or on built-up wooden or fireproof relay racks. At the signal locations at interlocking plants or at automatic signals, iron relay cases or wooden relay boxes are generally provided to house the relays, rectifiers, and other signal devices. Often the signal batteries are housed on the lower shelf of the iron case or wooden relay box, although some roads use a separate concrete or wooden battery box.

Signaling in main stations.

Practically all of the main stations or terminals in the United States are equipped with interlocking switches and signals, the latter being arranged to provide protection over all switches against conflicting movements, and in addition, protect against head-on and following movements. As these interlocking plants are located in areas where they must meet severe operating and traffic conditions, where the density of traffic requires quick operation of the switches and signals, and where reliability and safety of train operation are absolutely necessary, power operation rather than mechanical operation of the switches and signals is a necessity; the majority of the largest interlocking plants being of the electro-pneumatic type, and the remainder of the all-electric type.

Generally one interlocking switch or signal lever controls several switches or signals, depending upon the signal and track layout, although some roads follow the practice of having a separate interlocking lever for each operated unit. With a maximum number of operated units concentrated upon a minimum number of levers, instead of individual levers for each unit, the interlocking machine is of a smaller size. Thus a greatly reduced tower space and a lesser number of lever manipulations on the part of the tower operator are required. This results in the quicker clearing of routes for trains, permitting greater ease and saving in time of operation in moving from one to another part of the machine, besides affecting the amount of apparatus which must be maintained, and sometimes requiring fewer operators for the efficient and economical manipulation of the interlocking plant.

The interlocking machine levers are equipped with lever lights indicating block occupancy or signal or switch position. Switch levers are equipped with the proper indication and detector locking magnets to insure that the switches are in the locked position before signal levers can be operated. Signal levers are equipped with locks insuring that a route cannot be changed after a clear home and distant signal have been given, and a train has entered the approach section. Means, however, are provided through a predetermined interval on time releases for unlocking the route.

An illuminated track diagram is generally mounted over the interlocking machine to indicate by colored lights the

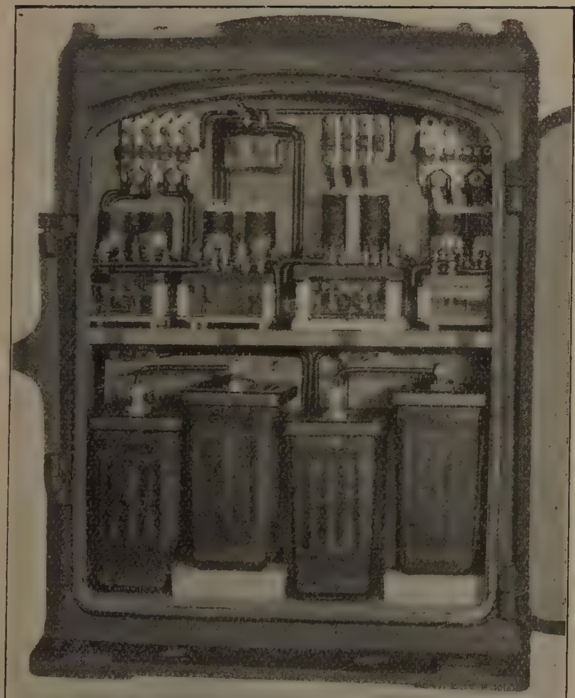


Fig. 12. — Metal relay and battery case for housing equipment other than in the signal tower.

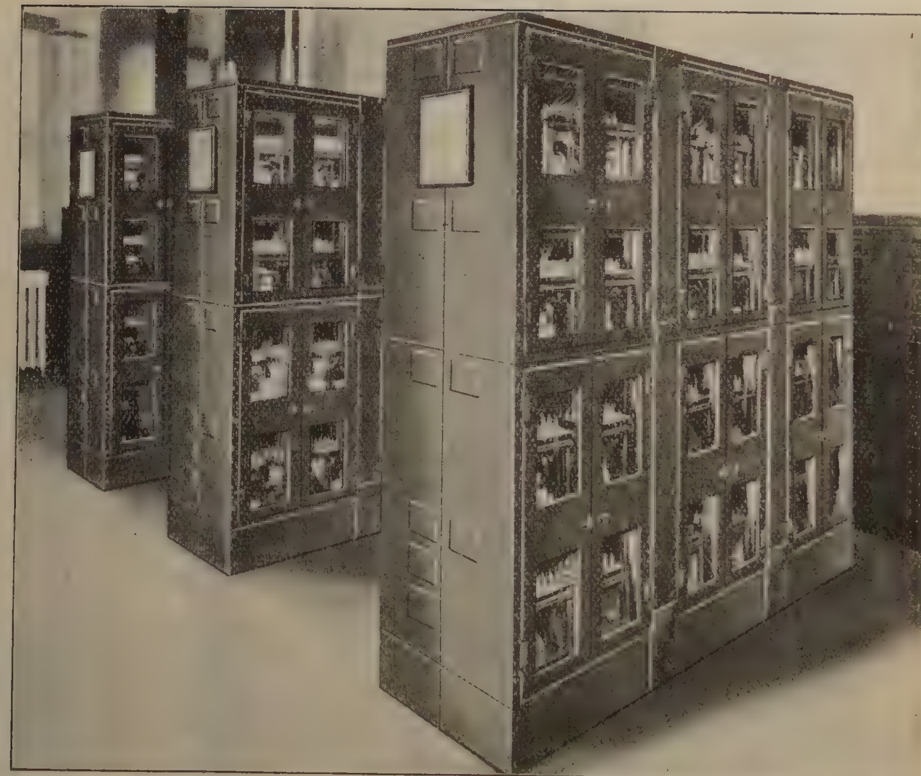


Fig. 13. — Steel relay and terminal case for housing equipment in the signal tower. Removable covers on wire channels provide for case in installation and subsequent inspection.

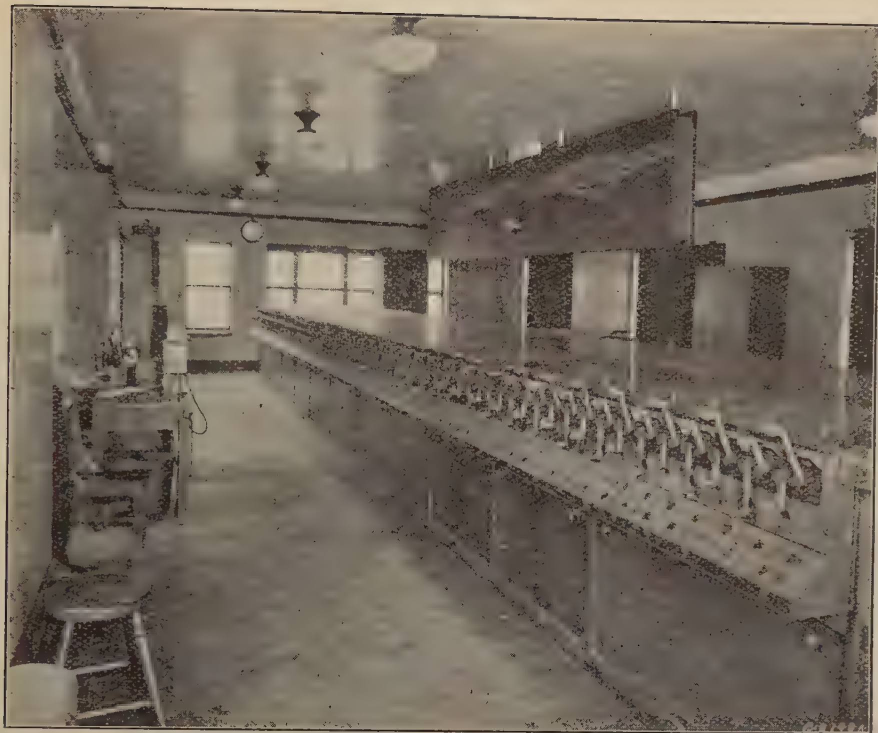


Fig. 14. — Power interlocking machine and illuminated track model at Chicago Union Station.

Fig. 15. — Track layout of one end of an electro-pneumatic interlocking at Chicago Union Station.

Fig. 16. — Color position light signal as used at interlockings.

movements of the trains on the various track circuits, the lights being continuously lighted in most cases, except when the block is occupied. The approach bells and clockwork time releases are usually mounted on the frame of the track diagram, on the end of or attached to the interlocking machine.

Separate control and indication circuits are generally provided, in the form of a polarized scheme of « SS » indication using a low voltage circuit, thus reducing to a minimum the liabilities of crosses and grounds, and insuring that the switches are in the proper position and locked before proceed signals can be displayed. Detector circuits controlled by continuous track circuits repeat the track conditions and act to prevent switches being operated under a train rather than by means of detector bars. Route lock-circuits are provided for advance locking of the levers in a route, but after the passage of a train the routes are released as soon as a conflicting route has been cleared.

While the largest number of the interlocking plants in main stations are equipped with three position upper quadrant semaphore signals, the more recent installations use light signals. While many of the older plants are equipped with three arm high signals, the latest plants are of the two arm type. It is the standard practice for the top arm of a semaphore signal or top unit of a light signal to govern train movements on the main line or normal route, while the other arm or light unit is retained for restrictive train movements. The tendency in the newer installations has been towards the adoption of dwarf signals for main routes rather than high signals due to the close clearances and restricted speed in congested city areas and the necessity for providing signals close to the fouling point of each switch or group of switches in order that the routes will be held the minimum length of time. Starting signals of the visual light type are generally provided, requiring the cooperation of the station master and the tower operator before signals are given for the train to leave the station.

On account of the necessity for reliability of operation, the power apparatus at a terminal interlocking plant is usually more complete than at a smaller plant

outside of terminal territory. Generally two or more power sources and automatic switching apparatus are available for use, and the main batteries for either the electro-pneumatic or all-electric plants are often in duplicate, with duplicate air-compressor motor-generator, rectifier and transformer devices ensuring continuity of service.

Generally the tracks between towers in main stations are signaled for the normal direction of traffic, and reverse train movements are only made under special instructions, although in a few cases, which will be described later, the tracks have been signaled for either-direction traffic without the use of train orders or other instructions. There is a growing tendency to extend the use of either-direction signaling as it permits the utilization of existing trackage at a fraction of the cost of new tracks, and saves time and delays in the delivery of the instructions for reversing the normal direction of traffic.

Intercommunication between towers is provided by telephones and visual or audible annunciators, and sometimes by train describers. Each tower is connected by telephone with the division or terminal train dispatcher, and by local telephones with adjacent towers and specified points near « stop » signals in the terminal territory.

South America.

Signaling of lines for fast traffic.

In reporting on the subject of signaling of lines for fast traffic and in main stations in South America, it is desirable to state that the standards and practices described are those of three roads in Argentina and one road in Chile.

While, in the past, there has been no organization in South America similar to the American Railroad Association in North America, in Argentina the Rules are now being standardized by the Argentina Railway Board in conjonction with the Railway Representatives. There is a South American Section of the Institution of Railway Signal Engineers of London at Buenos Aires and the signaling generally follows the English practice.

The automatic block signal mileage in Argentina is confined to a short territory adjacent to Buenos Ayres, totaling 12 km. (7.4 miles) of multiple track road in suburban territory.

While the engineman occupies the right side of the cab as in North America, the signals in Argentina are placed on the left side of the track either on the ground, on bracket masts or signal bridges.

The automatic and interlocking signals in Argentina are of the semaphore type and operate in two positions, lower quadrant, and three positions, upper quadrant. The automatic signal blocks in Argentina are spaced about 400 m. (1312 feet) apart when located in a busy territory between interlocking stations, although blocks up to 1 000 m. (3280 feet) in length may be used at other locations.

The signal aspects and indications of the automatic semaphore signals in Argentina are those ordinarily used with two and three position signals with two block indications. The two position first and second danger signals in the rear of an occupied block indicate «Stop», the third clear signal indicates «Proceed», while the fourth clear or repeater signal also indicates « Proceed ». The three-position first and second danger signal in the rear of an occupied block indicate « Stop », the third caution signal, 45°,

Fig. 17. — Color light signals governing high speed train movements through interlocking on Illinois Central Railroad at Chicago.

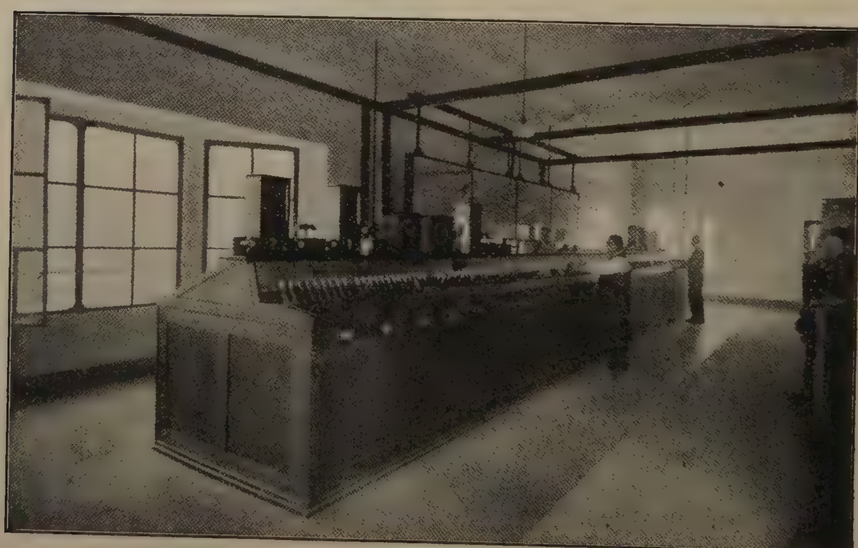


Fig. 18. — Electro-pneumatic interlocking machine at Temperley Junction, Buenos Ayres Great Southern Railway.

indicates « Proceed with caution », while the fourth proceed signal, 90°, indicates « Proceed at full speed ». Automatic signals are sometimes marked with the letter « A » to designate them from interlocking signals, but provision has not been made for permitting trains to pass automatic signals without stopping.

While some of the signal lamps are oil lighted, those in the larger terminal areas are electrically lighted at night only. These signals employ a 6-volt, 3-watt lamp, the power being supplied by direct current from the cabin battery. The power for the operation of the signals and track circuits is either supplied from the direct current cabin battery or primary batteries, or, as in the case of one road equipped with alternating current track circuits, with power from motor alternators. In general the track circuits and line circuits are of the direct current, neutral type.

The signal track circuits are bonded with two No. 8 iron or copper bond wires and channel pins at each joint. A No. 8 copper wire (or a 7/16 inch) is used for a track wire connection.

Insulated wires are used for signal circuits run as single conductors in wooden trunking in the ground or above the ground, in galvanized pipe or in fibre ducts, although a lead covered cable is sometimes provided.

At the signal locations in interlocking plants or at automatic signals, iron relay cases or wooden relay boxes and posts are generally provided to house the relays, transformers, and other signal devices, while wooden or concrete battery shelters are generally used.

Signaling in main stations.

It is the general practice to interlock all switches and signals in the vicinity of main stations with mechanical interlocking or with electro-pneumatic interlocking of the Englisch type, two of the largest electro-pneumatic plants being on the Buenos-Ayres Great Southern Railway, one at the Plaza Constitution Terminus, having a 279-lever locking frame, and another at Temperly Junction, having a 179-lever locking frame. Following the usual practice, one interlocking switch or signal lever in the electro-pneumatic machine controls several switches and signals, each lever being equipped with lever lights and indication magnets.

An illuminated track diagram is mounted over the electro-pneumatic interlocking machine to indicate by lights the movements of the trains on the various track circuits, the lights being continuously lighted except when the block is occupied.

These modern power-interlocking plants agree with the best North American and English practice. They have visual repeating indicators to inform the levermen whether or not signals respond properly to the movement of the levers; sectional locking is installed to prevent the operation of switches in advance of a train in the route to which a signal has been cleared, and these switches being automatically released upon the passage of a train over the various sections. Indication locking is provided on power operated signals to insure that the signal governed is in its most restricting position before the position of a switch in the route set can be changed. « SS » control is installed to independently insure that the position of all switches corresponds to the position of the lever before a signal governing over them can be made to indicate other than stop.

As has been mentionned before, the sig-

nals are of the semaphore type, those at the more modern plants being of the two arm, three position, upper quadrant type. Dwarf signals are not used for the principal train movements through terminals, but are used only for shunting movements. Semaphore train starting signals with route indicators are used, although in one case the station master rings a bell, the guard blows his whistle and exhibits to the driver a green flag or light, and the driver then starts the train, provided the starting signal is in the « Proceed » position.

The tracks are normally signaled for traffic in the designated direction and not provided for reverse traffic except in a few cases.

Intercommunication between towers is provided by telephones, an E. P. Combinator Descriptive apparatus as used on the London Underground, or by lock and block apparatus.

Chile.

The automatic block signal installation on the Chilean State Railways is interesting because it is the first installation of color light automatic block signals, built in accordance with signal practices of the United States to be installed in a South American Country. The road between Valparaiso and Santiago, Chile, and one branch line, a total of about 150 road miles, mostly single track, were equipped for 3 000 volt direct current electrification, necessitating the use of alternating current track circuits for the short section of signal territory. A 2 300-volt, 50-cycles, signal transmission line furnished the power, obtained from the nearest railway substation, 110 volts being used for the line relay and signal control circuits. Single rail and double rail track circuits, using 500 ampere rail bonds, were installed. The color light automatic block signals were of the home and distant type, the home signals were equipped with red and green lenses, and the distant signals were equipped with yellow and green lenses, 10 volt, 18 watt or 30 watt lamps being used in each signal.

British Empire.

Signaling of lines for fast traffic.

In reporting on the subject of signaling of lines for fast traffic and in main stations, it is desirable to state that the standards and practices described are those of twelve of the railway systems of the British Empire.

The art of signaling in Great Britain and the other countries has been developed through the work of the Institution of Railway Signal Engineers of London and its Associated Sections, while the standard rules and regulations for the roads are compiled by the Railway Clearing House.

Since 1889, by an Act of Parliament, the roads in Great Britain have been operating under an absolute block system on all railways under the control of the Board of Trade, now the Ministry of Transport, and this system is still in use except in the case of lines controlled by automatic signals and a comparatively few places at the entrance to terminal stations, goods yards and the like.

Of the 24 000 track miles of multiple track passenger lines, only a few miles of multiple track in fast traffic territory are equipped with automatic block signals due to the nature of the traffic, weight of cars, and the short distance between junctions and stations. The average distance between signal boxes or cabins is

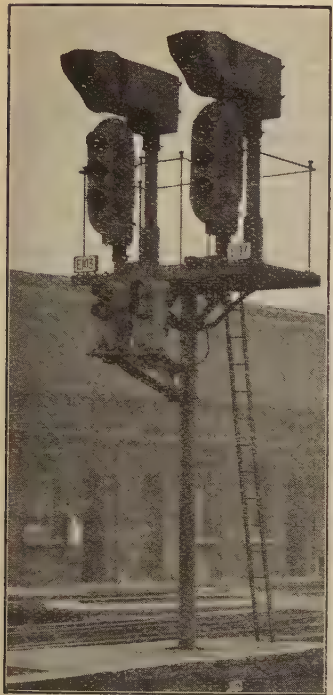


Fig. 19. — Color light signals with optical route indicators on London Bridge interlocking of the Southern Railway (Gt. Bn.).

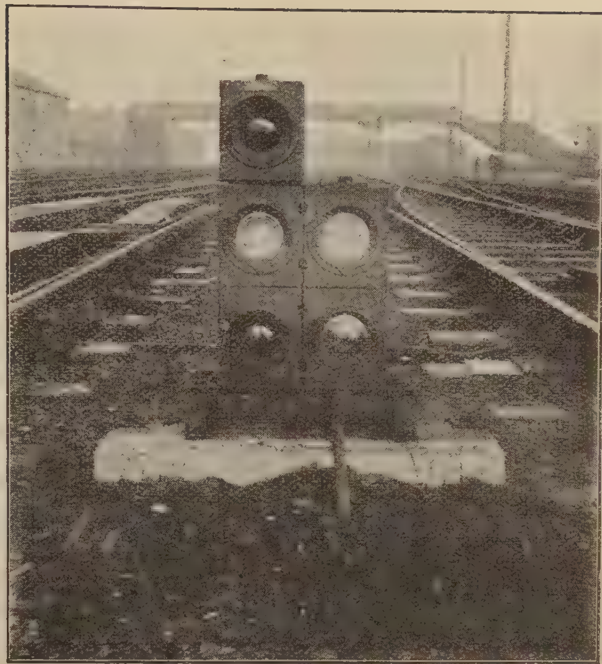


Fig. 20. — Shunting light signals of the type used at the Belfast Terminal of the London Midland & Scottish Railway.

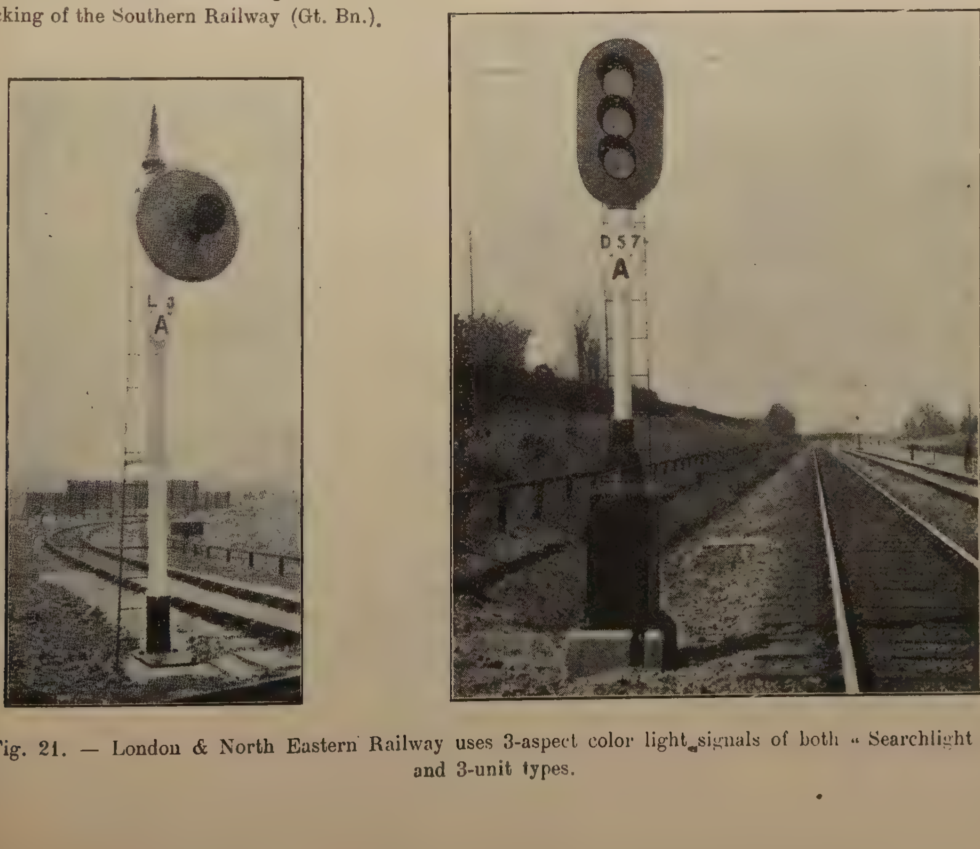


Fig. 21. — London & North Eastern Railway uses 3-aspect color light signals of both « Searchlight » and 3-unit types.

2.69 track miles, and between home and distant signals 1.01 track miles.

Of the 6 000 miles of single track passenger lines on the four large railway systems, about 5 440 miles, or 90 %, are protected by the electrical tablet, train staff, and key token systems, while up until 1927 only about 2-1/2 miles were protected by track circuits. A short mileage of automatic train control is in service on a few roads, which employ, generally, a mechanical or electro-mechanical system at control or distant signals. These systems were initiated in the first instance for fog signaling.

While in the United States and Canada, the engineman rides on the right hand side of the cab and the signal is on the right of the governed track, in Great Britain it is the general practice for the driver to ride on the left side of the cab and the signal is located on the left side of the track on the ground, on gantries or on signal bridges. The semaphore signals operate in the left hand quadrant rather than in the right quadrant as in the United States and Canada.

While the basis of the system of signaling for day working is the two-position semaphore arm, the use of light signals has been increasing since their introduction in 1921 until now the use of color light signals of two, three and four aspects is being adopted on new automatic signaling and interlocking installations. This change in practice is readily understood when it is realized that the light signals have the following advantages over the other types :

1. The same aspect by day and by night.
2. Increased penetrative power during unfavorable weather conditions which in some cases may enable fog repeaters or fogmen to be dispensed with.
3. Absence of moving parts, with consequent reduced maintenance.
4. Simpler mounting of signal.
5. Improved background of light signal.

Automatic signal blocks are generally spaced closer together than in the United States and vary with the traffic and local conditions on each road, but minimum lengths of 250 to 870 feet are in use while lengths of 1 200 to 3 000 feet are average for the longer blocks. In the British Dominions and Colonies, the short blocks are about the same, but the long blocks average from one to one and a half miles in length. The short blocks are used around terminals and on the Underground and at other points where the traffic conditions require the closer headway of trains.

There are a variety of signal aspects and indications, but in general on the new light signal installations, there are three types :

1. Two aspects, Red and Green. Red indicating « Stop » and Green indicating « Proceed ».
2. Three aspects, Red, Yellow and Green. Red indicating « Stop », Yellow indicating « Caution » and Green indicating « Proceed ».
3. Four aspects, Red, One Yellow, two Yellow and Green. Red indicating « Stop », one Yellow « Caution — Be prepared to find next signal at « Stop », two Yellow « Warning — Be prepared to find next signal at « Caution », and Green « All right — Proceed ».

The two-aspect signals give the aspects and indications conforming to the older type of two-position lower quadrant semaphore signals, the three-aspect signals correspond to those given by the three-position upper quadrant semaphore sig-

nals, and the four-aspect signalling provides the approach restricting indication used in three block signalling in the United States. The additional aspect, that is, two yellow lights, is therefore less restrictive than a single yellow, and more restrictive than a green light.

It is the general practice for trains to pass automatic block signals in their most restrictive position after waiting one to three minutes, but no cases of proceeding by such signals without stopping when the block is occupied was reported. Slow speed or call on movements are provided for by interlocking signals. The stop and stay interlocking signals must not be passed without instructions of a responsible official. Continuously lighted signals are generally used, although some approach lighted signals are in service.

The power for automatic block and interlocking signals is generally obtained from an alternating current source of supply at a voltage of 60, 100, 110, 400, 440, 600, 2 000, 2 200, or 3 000 volts, single or three phase, 50 cycles, although some 33-1/3 and 75 cycle power is used. For local circuits 60, 100, 110, or 220 volts is used with the necessary transformers, protective and cutout devices.

Alternating current track circuits are generally used, although some direct current track circuits of the storage or primary battery type are in use. Both the neutral and polarized type of track circuits are in service. For the ordinary track circuit outside of electric traction territory, the use of two No. 8 galvanized iron, copper, or copperweld bond wires bonded around the rail joints with channel pins is the general practice. Some of the copper bond wires are of the flexible type, but solid wires are generally used. Solid and flexible copper wire track connections are used between the track relays and the rails.

Although in the United States and Canada it is the usual practice to have non-interlocked switches in fast traffic territory, in Great Britain, its Dominions and Colonies, it is the practice to interlock or provide facing point protection on all switches, either of the facing point or trailing type.

The majority of reporting roads state that their signal control circuits are in underground lead covered armoured cable, run in fibre or creosoted wooden ducts, the wires being protected with rubber or paper insulation. Some galvanized iron pipe and concrete troughs have been used. In two cases where aerial construction was used, the wires were either copper or bronze with rubber or paper insulation with a tape and braid, and supported by messenger on the pole route.

The general practice appears to favor the use of cast iron relay cases for housing the relays and transformers, although in some cases wooden cabinets are used for such purposes, particularly at the signal boxes, and for housing the batteries. In one case the transformers were housed in an asbestos cement hut.

Signaling in main stations.

The main stations or terminals in the British Empire are equipped with interlocking switches and signals. While the smaller size plants are of the mechanical type, the larger plants are power operated; the largest interlocking plants being of the electro-pneumatic type, and the others of the all-electric type.

Generally one power interlocking switch or signal lever controls several switches or signals, although the practice

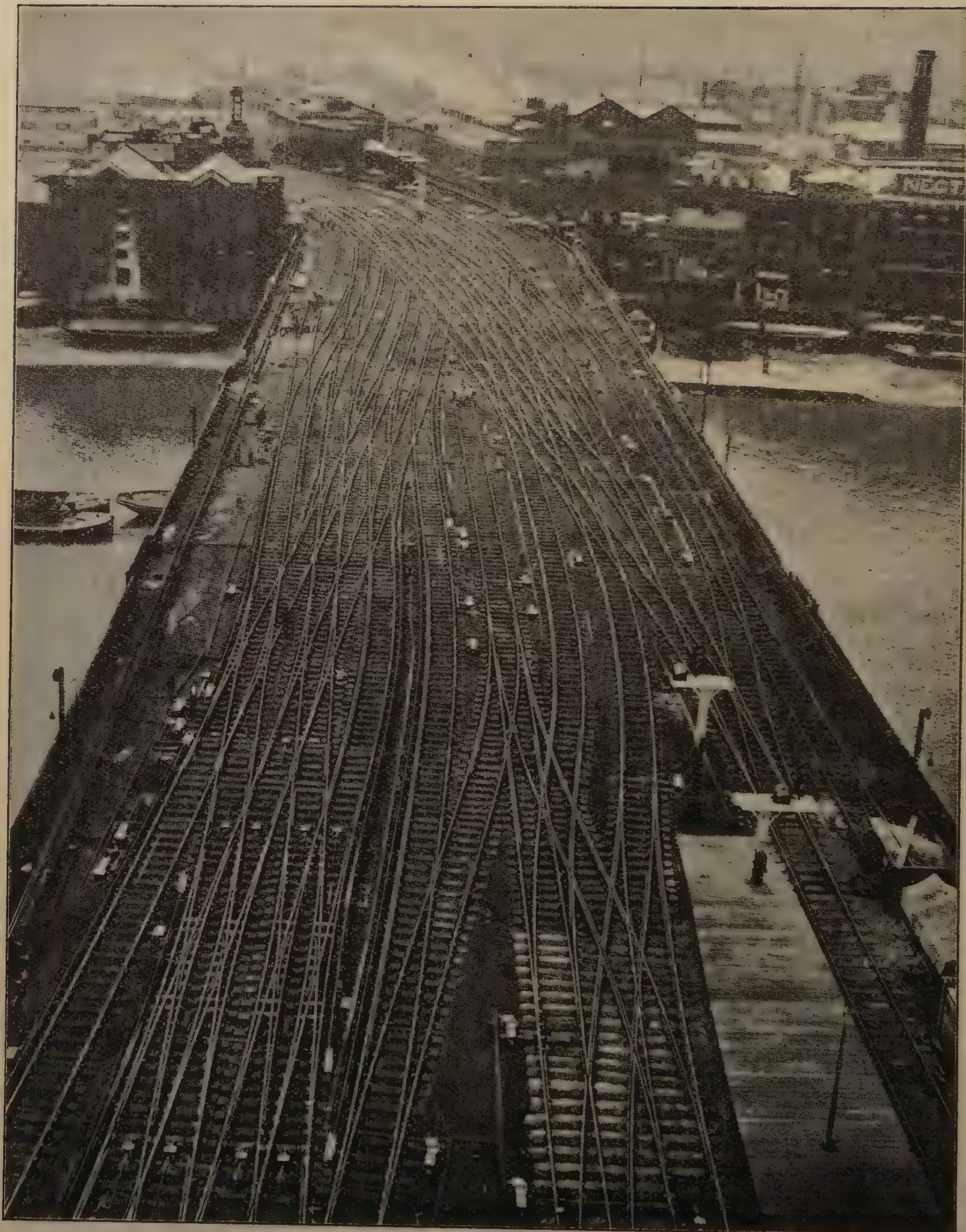


Fig. 22. — Track layout at Cannon Street, Southern Railway (Gt. Bn.).

of having a separate interlocking lever for each operated unit is also used, and especially at mechanical interlocking plants.

The power interlocking machine levers are equipped with lever lights for signal and point repeaters while the track repeaters are shown in an illuminated track diagram above the interlocking machine. On the track diagram, the lights burn continuously except when the block is occupied.

On some of the plants detector bars are used in lieu of detector circuits, but on the newer and more modern plants, the switch levers are equipped with the proper indication and detector locking magnets to insure that the switches are in the locked position before signal levers can be operated; signal levers are equipped with locks so that a route cannot be changed after a clear home and distant signal has been given.

The signal circuits are selected through the « SS » or switch detection relays which insure the switch and controlling lever being in corresponding positions, and route locking circuits are provided for advance locking of the levers. The length of the approach section varies, with traffic conditions, from 50 feet to 200 feet in some cases of fast traffic.

The signaling at the main stations is either of the semaphore or color light types, the latter being used on the more modern installations. Two, three and four aspect color light signals are used, giving the indications previously mentioned. In addition, color light repeater signals, generally two aspect, are used in fog territory, while route indicators of the projector type, hereinafter described, and mounted over the color light signal, are provided on some of the recent installations. The main line or normal route signal is given by the top light and low speed or shunt train movements are given by the lower lights of the interlocking signal. It has not been the practice to use dwarf signal indications to convey the same meaning as the larger main line type; dwarf signals are seldom controlled by track circuits. Train starting signals of the two-aspect color light type, semaphore signals, audible signals, or an illuminated sign are sometimes used, but before starting his train the driver receives a visible signal consisting of a green flag or green light from the guard or conductor of the train.

Generally two or more power sources are available at the main interlocking plants and the main batteries for each power plant are often in duplicate, with duplicate motor generator or rectifying devices as well as transformer devices ensuring continuous service, the power apparatus being arranged so that in case of failure of the normal source of supply, the emergency supply is automatically connected to the plant. On one recent installation the entire power layout is operated by alternating current except the direct current point machines which obtain the necessary 110 volts D. C. from duplicate three phase rectifiers, thereby eliminating the usual rotating machines and storage batteries.

Generally the tracks between signal boxes at main stations are only signaled for the normal direction of traffic, although in a few cases for short distances the tracks have been signaled for either direction traffic.

Intercommunication between signal boxes is provided by ordinary block instruments, magazine train describers operated by levermen and automatically cancelled by the trains, or by hand at the receiving end by audible signals under

a special bell code, by visual signals and by telephone communication.

The signaling on the London Underground is of special interest on account of the heavy traffic of 40 trains per hour in each direction. The Underground System of 160 track miles is completely equipped with A. C. track circuits of the single rail type, except on one line where double rail track circuits are used. Points, operated from power frames, and all semaphore signals and train stops are worked by compressed air which is controlled by electrically operated valves, except on one section, which is all-electric A. C. In the tunnel and tube sections and on the new lines the signals are of the two aspect light type, while on the older portions of the lines the signals are of the two position semaphore type. Automatic signaling is generally used except where switches are provided, necessitating lever control of the signals. Information as to which track circuits in his control area are occupied is conveyed to the signalman by means of an illuminated diagram. A system of train description is in use on a considerable portion of the lines between signal cabins, and this system is also used for illuminating platform destination signs at intermediate stations. The principle of the operation is as follows :

The signalman at the end of the line or section sends a description of each train as it leaves the station. These descriptions are received and stored up at each station throughout the section and in the signal cabin at the end thereof, and are shown up on signs in their correct order. As each train passes out of a station or section, the description applying to that train is automatically cancelled, and that of the following train is shown up in its place. The descriptions are transmitted from one end of a section to the other by means of only four wires, and upon which fifteen different descriptions can be obtained.

On the Liverpool Overhead Railway, 6 3/4 miles of double track two-aspect color light signals and train stops are in service. The track circuits are of the single rail A. C. type and average 1 200 feet in length. The « Stop » position of each signal is overlapped 300 feet into the block ahead.

British Dominions and Colonies.

The principles of British signaling generally applies to the railways in Australia, Africa, New Zealand, India, and the Colonies, but the varying condition of traffic, climate and other local conditions, necessarily alter the application of these practices which have worked out so successfully in Great Britain and the United States. There are, however, some special notes of interest to which special attention is called.

New Zealand.

Generally the signal indications in New Zealand are the same as those adopted by the American Railway Association in the United States while the general practice is in accordance with British signaling. The Railway Board issued in September 1927, a set of « Regulations for Automatic Signaling with Three-position Upper Quadrant Semaphore and Color Light Signals » which specifies the rules and shows the aspects and indications of the automatic signals installed on the New Zealand Government Railways.

Color light automatic block signals have been installed on 233 miles of track,

196 road miles, of which 159 miles is single track the first installation being about 1920. The automatic signals are of the three aspect type with a staggered marker light and the interlocking and absolute signals are distinguished by the lights being displayed in a vertical line. Red indicates « Stop », yellow indicates « Caution » and Green indicates « Clear ». In local areas the automatic signals are spaced about 1/2 mile while the longer blocks are 1 1/2 miles apart. Due to the fact that the engineman is on the right hand side of the cab, the signal is located on the right hand side of the track. The automatic block semaphore signals, however, are the three position, upper left hand quadrant type. On the single line automatic sections, the starting signals are normally at « Stop » with a special arrangement of operation at crossing loops. Points are set normal for the main line, and when a train approaches a crossing place, provided that there is no other train approaching in the opposite direction, the starting signal from the crossing is cleared and a train which is not scheduled to stop at that crossing may proceed. When points are set for loop, letter « L » appears below the home signal indicating that points are correctly set for the loop road. While permissive signals may be passed after waiting ten seconds, unless driver is aware that the section ahead is occupied, the « Stop » signals may be passed only with authority from an official or from the train control office. At practically all stations the interlocking frame is installed in the station-master's office. All-electric and electro-pneumatic power interlockings are used and equipped with spot light type illuminated diagrams. In the vicinity of Auckland and Dunedin, there are some sections of double track automatic signaling. At interlockings the points are mechanically worked and the signals are controlled from the mechanical levers which were originally used for operating the semaphore arms. Alternating current is used for the polarized track circuits and power for lighting of the signals and operation of the control circuits. The signal control circuits are of triple braid, weatherproof copperweld, copper or bronze run over-head on open line construction.

Australia.

Color light automatic block signals of the two-aspect type have been installed in suburban territory on the New South Wales Government Railways on 91.5 miles of track, 30.5 road miles, of which 1.5 miles is on single track, 2 two-aspect signals being generally used, either of which can show red or green. Two Reds mean « Stop »; Green over Red, « One block clear »; and Green over Green indicates « Proceed, two or more sections clear ».

The block lengths are short, averaging about 800 feet in length. The track and line circuits are of the alternating current neutral type supplied from à 2 200 volt, 50 cycle, power line. Single conductor, insulated wires for signal control circuits are run in creosoted wood ducts, and an armoured cable is used for the high tension mains. The relays and transformers are housed in concrete huts, which are sub-divided into transformer and relay divisions. The interlockings are of the electro-mechanical all-electric or electro-pneumatic type, the control being either A. C. or D. C.

On the Victorian Railways day color

Fig 23. — South African Railways.

Fig. 24 — New Zealand Government Railways

Fig. 25. — Victorian Government Railways, Australia.

Fig. 26. — Liverpool Overhead Railway (England).

Fig. 23 to 26. — Installations of daylight signals in the British Empire.

light signals of the three aspect type are used. Power interlockings of the all-electric A. C. type are used, embodying approach locking and sectionnal release interlocking where required.

Africa.

An interresting installation of day color light signaling has recently been placed in service on the South African Railways in the Capetown suburban territory where a 22-mile electrification was installed. The automatic block signaling includes 2 1/4 miles of multiple track and 6 miles of double track, and a new all-electric interlocking plant at Capetown. This modern installation is of special interest, as, although the mileage of the railway is about 12 600, so far mechanical signaling has been able te cope with the demands of train operation; but with about 450 train movements under steam operation with an additional 624 engine movements in about 20 hours of the day, an improved type of signaling was necessary. The color light automatic block signals were of the three-aspect type, spaced from 600 to 1 200 feet apart, but a departure was made at interlocking plants by also using one-position and two-position shunt signals of the position light type. The one-position light shunt signal is used when it is placed under or alongside a running color light signal, as the Red aspect of that signal forms the danger signal to the driver. Two-position light shunt signals are used for controlling movements from sidings to the running lines, or from one siding to another, or for set back shunt movements. The caution signal is given by two white lights only being shown at an angle of 45° in the left hand upward direction. Route indicators of the projector type give numbers of platforms and work with the color light signals. A feature of interest in connection with the track circuits, which are fitted with impedance bonds, is the arrangement of the feed and relay connections. The bonds are fitted with primary and secondary windings, the latter being connected to a condenser for the purpose of improving the power factor and the impedance. The track leads, instead of being connected to the rails, are connected to suitable tappings on the secondary winding. The feed and relay currents are thus at higher than rail voltage and the currents correspondingly reduced. The track feed transformers and track relays can be installed at considerable distances from the rails, and in many instances are fixed in the signal cabins 1 800 feet or so away. Teak relay cabinets are used in signal cabins and iron cases in the open. A 2 200 volt, 50 cycle, power line furnishes 110 volts A. C. for the track circuits and signal controls, while a static rectifier floats the 110 volt storage battery. Insulated cables were suspended from a straining wire supported on concrete posts placed about 15 feet apart. For runs across tracks the cables were placed in fibre ducts surrounded by concrete.

India.

The general rules for all open lines of railway in British India administered by the Government were issued by the Railway Board in 1906. The Victoria Terminus Station of the Great Indian Peninsula Railway and 8.86 miles of double track electrified suburban line have been equipped with color light signals. The automatic signals are similar to the home and distant semaphore type

and are composed of two light units of two aspects, each providing Red over Red for « Stop »; Green over Red for « Proceed, prepared to stop at next signal », and Green over Green for « Proceed ». A. C. track circuits of the single and double rail type and signal circuits are provided, the power being supplied from a 2 200 volt, 50 cycle, 3 phase distribution system. The control wires are run in armored cable buried in the ground. While the engineman is located on the right hand side of the cab, the wayside signals are on the left of the track governed. Interlocking plants of the mechanical, electro-mechanical and electro-pneumatic types are in use.

On the Bombay, Baroda and Central India Railway, 2 1/2 miles of double track, two aspect, red and green, color light automatic block signals are in service on a section of electrified track. The blocks average 1 000 feet in length and are controlled by A. C. neutral track circuits supplied from 110 volt A. C. mains. The control wires are in armored cables buried in the ground.

Japan.

Signaling of lines for fast traffic.

The automatic block signaling for fast traffic lines in Japan, in general, follows the practice of the United States as previously to the introduction of color light signals in 1923, the three position upper quadrant semaphore signals were of the North American type. Automatic block signaling of the color light type is in operation on 888.4 km (about 552 miles) of track, 390.4 km. (242.6 miles) of road, of which 336.6 km. (209.3 miles) is double track and 53.8 km. (37.3 miles) is four track, on the Japanese Imperial Government Railways and, in addition, on about 476 miles of track of the privately operated electric lines. Following the English practice, the engineer rides on the left hand side of the cab, and the wayside signals are located on the left hand side of the track.

The automatic signal blocks are generally spaced about 1.5 to 2.0 km. (0.93 to 1.24 miles) apart with three aspect color light signals, Red, Yellow and Green. Red indicates « Stop »; Yellow indicates « Proceed(prepared to stop at the next signal »; and Green indicates « Proceed ».

The signals are continuously lighted from a 3 300 volt, 50 or 60 cycle, transmission line supplied from commercial power systems. The track circuits are of the polarized type using three position A. C. relays while the line circuits are of the neutral type.

In electrified territory, two stranded, soft copper bond wires are used, but for steam road operation two hard copper or steel wires are bonded around the rail joints. All facing point switches and some trailing switches, are normally interlocked while those non-interlocked are provided with switch circuit controllers.

No. 10 copper insulated wires are run underground in trunking, and lead covered and armored impregnated cable are run underground in creosote wood ducts, very little open line construction being used. Cast iron relay boxes located at the base of the signal, house the relays and transformers. Provision has been made to provide permissive signals on grades to permit tonnage trains to enter an occupied block without having first brought the trains to a stop.

Signaling in main stations.

It is the general practice to interlock all switches and signals in the vicinity of

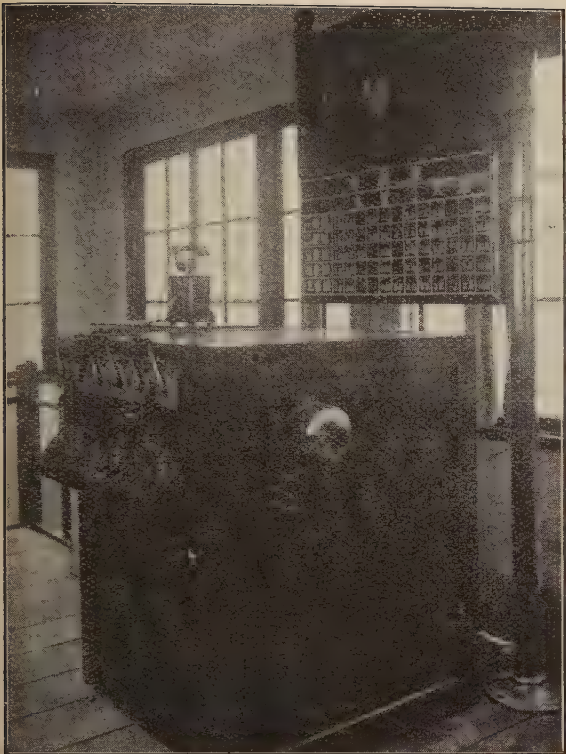


Fig. 27. — Power interlocking machine, Osaka Terminal, Shin-Keihan Railway, Japan.

Fig. 27a. — Automatic signal, Japanese Government Railways.

Fig. 28. — Electro-pneumatic interlocking, Japanese Government Railways.

main stations or terminals with mechanical machines or power machines of the electro-pneumatic or all-electric types. Around the main stations and in suburban territory the color light signal blocks are 900 feet to 1 800 feet or 3 000 feet in length. On the Japanese Government Railways, the high signals at interlocking plants are of the color light type and the dwarf signals are of the three position upper right hand quadrant position light type. It is the practice to use dwarf signals for principal switching movements. Train starting signals are used at only a few places, some being audible and others being audible and visible.

China.

The automatic block signaling for fast traffic lines on the South Manchuria Railway Company in China generally follows the practice of the United States. Automatic block signaling of the color light type is in operation or under construction over the entire double track line of 189.6 km. (117.8 miles), or 379.2 km. (235.6 miles) of track. As in Japan and England, the engineer rides on the left hand side of the cab and the wayside signals are located on the left hand side of the track.

The automatic signal blocks are spaced about 3 000 m. (9 842 feet) apart with three aspect color light signals, Red, Yellow and Green. Red indicates « Stop », Yellow indicates « Approach next signal prepared to stop », and Green indicates « Proceed ». Trains are permitted to enter an occupied block at low speed without stopping, by a special indication given by a purple marker light. The signals are continuously lighted from a 3 300 volt, 3 phase, 50 cycle transmission line.

The track circuits are of the A. C. polarized type using three position A. C. relays, while the line circuits are of the neutral type. Two No. 6 B & S copper wires are bonded around the joints by means of a duplex channel pin.

Switch and lock movements with electric locks and circuit controllers are attached to all facing point switches, although on trailing switches a circuit controller and switch indicator are provided.

No. 14 rubber insulated wires are used for signal circuits with one No. 14 × 7 stranded copper wire for a common return. For aerial lines, No. 6 rubber insulated wires are used, while on underground construction No. 14 rubber insulated wire is run in gas pipes or trunking, although lead and armor cable is sometimes installed in terminal areas, but single conductor is generally used. Cast iron mechanism cases and special iron boxes house the relays and other signal devices.

It is the general practice to interlock all switches and signals in the vicinity of main stations or terminals with either mechanical or all-electric plants. The signals are of the color light type and give two or three indications. Dwarf signals are used for principal movements through terminals to convey the same indications as high signals. Detector bars are used at the stations without track circuits, but at the main stations continuous track circuits and detector locking are employed. Electric bells and starting indicators are used for starting signals. Except on the main line the tracks at main stations are operated in both directions. Intercommunication between towers is provided by telephones and annunciators.

United States and Canada.

Daylight signals.

In the United States and Canada there are three distinct designs of daylight signals :

a) Color light (figs. 29 to 32).
b) Position light (fig. 33).
c) Color position light (fig. 34).

Tables I and II show the main difference in detail characteristics between these signals.

Color light signals.

Color light signals, as the name implies, convey the signal indication by means of colour, usually red, yellow and green. There are four distinctive designs.

Fig. 29. — Vertical lamp unit assembly, 2 or 3 colors.

Fig. 30. — Triangular lamp unit assembly, 3 colors.

Fig. 31. — Horizontal lamp unit assembly, 2 or 3 colors.

Fig. 32. — Searchlight, one lamp unit, relay mechanism affording selection of 2 and 3 colors.

A fifth type of color light signal in use is that provided by the adaptation of a high power lamp behind the colored semaphore roundels of the ordinary semaphore signal.

Signals, figures 29, 30 and 31, differ mainly in the disposal of the lamp units All three types are used for both automatic signaling and interlocking applications, although the signal having the horizontal lamp assembly has more specific application for bridge mounting or where vertical clearances are restricted. A few typical combinations af the 3-light units are shown in figure 35.

The light units in these signals are assembled in waterproof cast iron cases. The front face of each case is very accurately machined so that the individual lamp units when assembled thereon have the same alignment. There is another design, figure 31, of the color light signal having similar appearace except that the lamp units are placed in individual cast iron cases which may be assembled to make up a complete signal.

Light signals are equipped with individual lamp transformers, backlights, terminal boards, light out relays, etc., to suit varying requirements. Backgrounds are universally used for long range high speed traffic and each light is shielded from the direct rays of the sun by suitable hoods.

These signals are designed for mounting either on the top of the mast or on the brackets clamped to the side of the mast. In either case horizontal and vertical adjustment of the complete high signal is provided.

Figure 36 shows a section view of a typical color light signal in which the front lenses are clear and the inner lenses are either red, yellow or green. Each lamp unit assembly is known as a doublet lens assembly and has the advantage that a very large percentage of the illumination is utilized. The lamp receptacle is supported in a fixed relationship to the lens combination and as it is recommended that the filament of all lamps be accurately located, renewal of lamp may be made without readjustment. The inside face of the lens casting is accurately machined so that each unit will be in perfect alignment when fastened to the correspondingly machined surface on the front of the signal case. Lamp assemblies of this design may usually be removed as a unit from the front of the signal.

Important characte

Types (high signals).	*Lamp assembly.*	*Mounting.*	*Lamp unit adjustment.*	*Provision for sig*
Color light.	Vertical, 2 or 5 lamp units.	Bracket and top post (adjustable).	Accurately aligned with case (fixed).	Yes.
	Horizontal, 2 or 3 lamp units.	Bracket and top post (adjustable).	Accurately aligned with case (fixed).	Yes.
	Triangular, 3 lamp units.	Bracket and top of post (adjustable).	Accurately aligned with case (fixed).	Yes.
	Searchlight, one lamp unit.	Bracket for side and top front or mast (adjustable).	Socket (adjustable).	Yes.
Position light.	Various (see aspects).	Bracket (semi-adjustable).	Individual.	No.
Color position light.	Various (see aspects).	Bracket (semi-adjustable).	Individual.	Yes.

light signals.

nsing system.	*Provision for spread.*	*Type filament.*	*Lamp : volts and watts.*	*Adjustment.*
et rear lens /2", front lens /8".	Auxiliary prisms.	Concentrated filament rebased for bayonet socket.	10 v. — 18 w. 8 v. — 10 w.	Accurate.
et rear lens /2", front lens /8".	Auxiliary prism.	Concentrated filament rebased for bayonet socket.	...	Accurate.
et rear lens /2", front lens /8".	Auxiliary prism.	Concentrated filament rebased for bayonet socket.	10 v. — 18 w. 8 v. — 10 w.	Accurate.
ical reflector and /8" lens.	Auxiliary prism.	Concentrated filament rebased for bayonet socket.	11 v. — 11 w. 8 v. — 10 w.	Accurate.
" inverted toric with amber co- al cover glass.	Reflector cover glass toric lens.	Concentrated filament rebased for bayonet socket.	12 v. — 9 w.	Accurate.
et rear lens /2", front lens /8".	Prisms.	Concentrated filament rebased for bayonet socket.	13 1/2 v. — 17 w.	Accurate.

Fig. 29. — Vertical.

Fig. 30. — Triangular.

Fig. 31. — Horizontal.

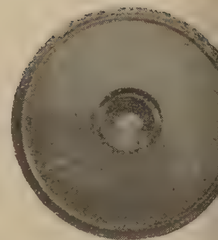


Fig. 32. — Searchligh

Figs. 29 to 32. — Color light signals.

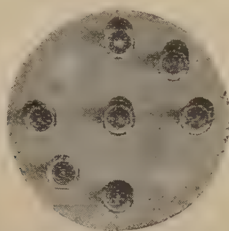


Fig. 33. — Position light.

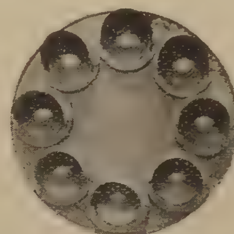


Fig. 34. — Color position light.

Figs. 33 and 34. — Daylight signals (high types).

Such a light unit as has been described provides a long range indication with reasonable spread. For application to curves and conditions where the signals are located above or far to the side of a locomotive standing at or approaching the signals, it is necessary to resort to the use of various deflecting means. Most lamp units permit the application of a deflecting prism glass in front of the main lens, while for « close up » indication special small deflecting units are often used between the lenses of the doublet combination.

Color light signals of the type described above are made in similar models for use as dwarf signals. However, this applies specifically to the signals having vertical and triangular assemblies of lamp units as shown in figure 37. The range of dwarf signals need not be as great as that of high signals and consequently it is customary to use smaller size lenses and less precision in the location of the lamp with respect to the lens.

Dwarf signals having vertical alignment of lamps may be equipped with either two or three lamp units, while the triangular assembly obviously requires three lamp units. These units are assembled in water-proof cast iron cases having doors which allow access to the vital parts for inspection. The bases for these signals usually provide for sufficient tilt so that the signal indication may be viewed from above.

Another type of color light signal commonly used is known as the searchlight signal. The one lens used is clear, the colors red, yellow and green being obtained by the introduction, between the lamp and objective lens, of a moveable

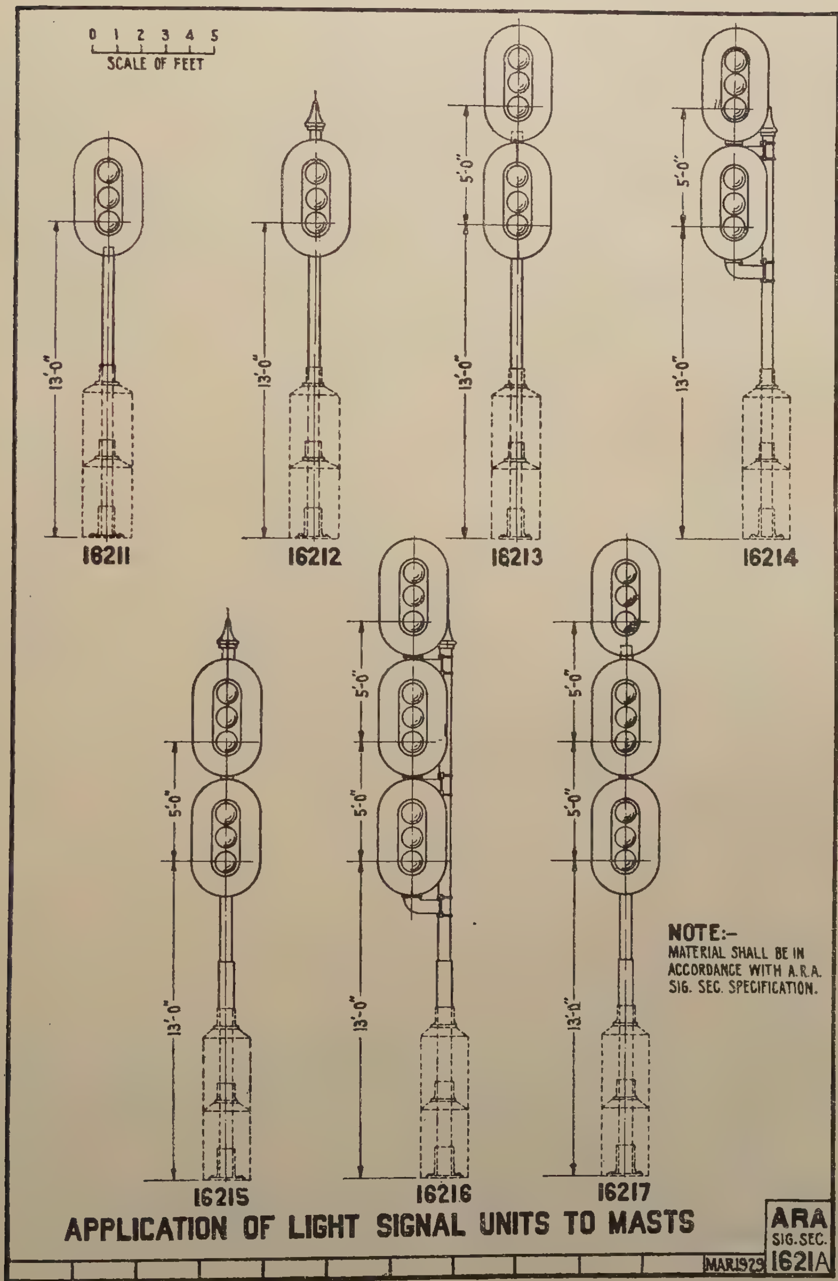

0 1 2 3 4 5
SCALE OF FEET
13'-0"
5'-0"
16211
16212
16213
16214
16215
16216
16217
NOTE:-
MATERIAL SHALL BE IN ACCORDANCE WITH A.R.A. SIG. SEC. SPECIFICATION.
APPLICATION OF LIGHT SIGNAL UNITS TO MASTS
ARA
SIG. SEC.
MAR 1929
1621A

Fig. 35.

Important charact

Types (dwarf signal).	*Lamp assembly.*	*Mounting.*	*Lamp unit adjustment.*	*Provision for si*
Color light	Vertical, 2 or 3 lamp units.	Foundation.	Aligned with case.	No.
	Triangular 3 lamp units.	Foundation.	Aligned with case.	No.
	Searchlight, one lamp unit.	Adjustable base on foundation.	Socket (adjustable).	No.
Position light.	Radial quadrant, 2 and 3 positions.	Foundation.	None.	No.
Color position light.	Radial quadrant.	Foundation.	None.	No.

vane carrying three small colored roundels. This type of signal is illustrated in figures 32 and 38. Two types of supporting arms are furnished for high signals. One type is designed for side of mast mounting, the center line of the signal being approximately nine (9) inches from the center line of the mast. Another type of supporting arm is furnished providing for front of mast mounting. In this case the signal is usually located at the top of the mast. The high signal is furnished with a circular background and is equipped with a sighting device for aligning the signal. « U » bolts are used for fastening the supporting arm to the mast. Both vertical and horizontal mounting adjustments may be made readily.

The searchlight dwarf signal, fi-

ylight signals

ensing system.	Provision for spread.	Type filament.	Lamp : volts and watts.	Adjustment.
let rear lens 1/2", front lens 3/8".	Auxiliary prisms.	Concentrated or distributed filament.	10 v. — 18 w. 30 v. — 36 w.	Accurate.
» »	» »	» »	» »	»
let rear lens 1/2", front lens 3/8".	» »	Concentrated.	11 v. — 11 w. or 8 v. — 10 w.	»
tical reflector and 3/8" lens.	Frosted lens.	Concentrated filament	6-8 v. — 16-8 w.	None.
" frosted lens.	...	...	...	...

gure 37, has the same construction as the high signal except as to the lens and deflecting prism cover glass; also it is not provided with a background and sighting device, and is fitted with a base suitable for mounting on a flat surface such as a concrete foundation, instead of a supporting arm.

Up to the present the direct current type of searchlight signals has met with greater favor and this report deals strictly with the direct current operating mechanism. It is essentially a three position motor relay, harving field or local coils and an operating or armature coil. The moving element is an iron armature which rotates approximately thirteen and one-half degrees (13-1/2°) each way from the center position, at which it stands, due to counterweighing,

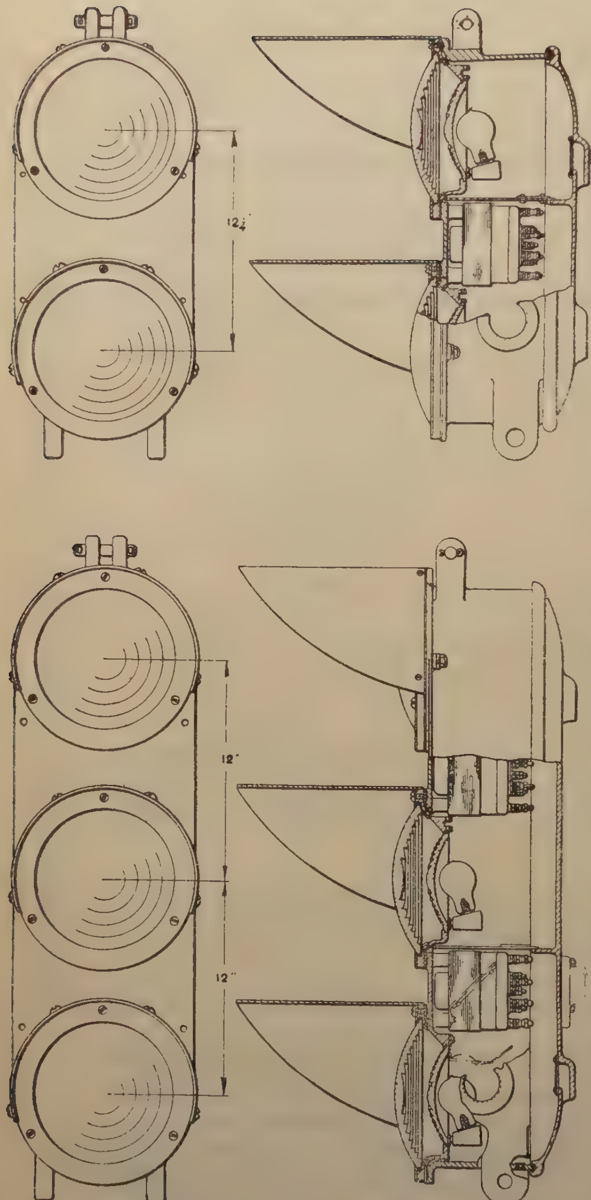
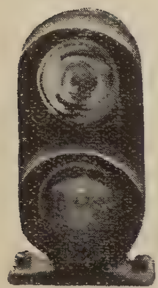


Fig. 36. — Two and three light color light signals, showing doublet lens assembly.

when de-energized. Directly connected to the armature shaft is a small spectacle in which are mounted three colored glass roundels, each of one inch diameter. These roundels are moved into the concentrated light beam, as required, by the movement of the armature. In standard three-color light signaling, the red roundel is located in the center and is in the light beam when the armature coil is de-energized. With a constant potential applied to the local or field coils, current passed through the armature coil in one direction rotates the armature against a stop to bring the yellow roundel into the light beam. Current passed through the armature coil in the other direction rotates the armature in the opposite direction against a stop to bring the green roundel into the light beam. Thus the required change in colors is effected. For two color light signaling the armature is rotated only in on direction.

The light beam is concentrated at the colored roundel location by means of an elliptical glass reflector, which, with the lamp, lamp socket and reflector holder as a unit, is inserted and held in place with spring clips in the back of the relay top case. It is characteristic of the elliptical reflector that, with the lamp filament located at the focal point of the reflector, the reflected light is concentrated at the other focal point of the complete ellipse, which in this signal relay is approximately the location of the colored roundel. After passing through the colored roundel, the beam spreads out to cover the lens in the outer case, which condenses the light rays into a concentrated beam. The lamp socket is adjusted and sealed at the factory and accurately based lamps may be placed in the socket without any readjustment.

While the standard objective lens is 8 3/8 inches in diameter, a 10 3/8-inch

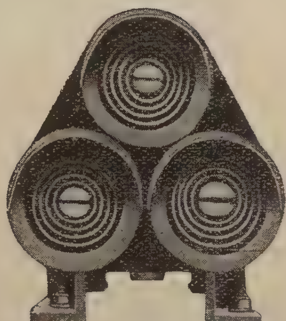


Two light
color light signal.

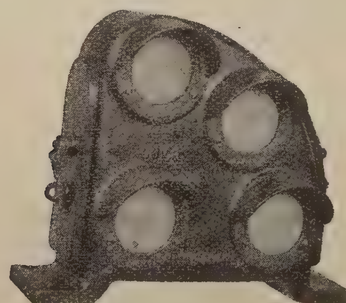
Searchlight signal.

Color position
light signal.

Three light
color light signal.



Triangular
assembly color light signal.



Position light
signal.

Fig. 37. — Varions types of daylight dwarf signals.

lens is sometimes used and there are various methods of caring for beam spread. The lamp used in the searchlight signal is usually 11 volts, 11 watts and it is mounted in an adjustable socket above the operating mechanism in relation to an elliptical reflector.

Position light signals.

Position light signals present aspects and give indications by means of rows of light corresponding to the positions occupied by the blades of a semaphore signal, light indications being visible during both day and night. High signals may be mounted upon a ground mast, signal bridge or cantilever post. They can be arranged to give indications corresponding to the one arm, one arm with marker, two arm, or any other combination desired. Each arm or blade equivalent can give one, two, three or four distinct positions. A complete arrangement of aspects and indications for position light signals is covered in figure 39.

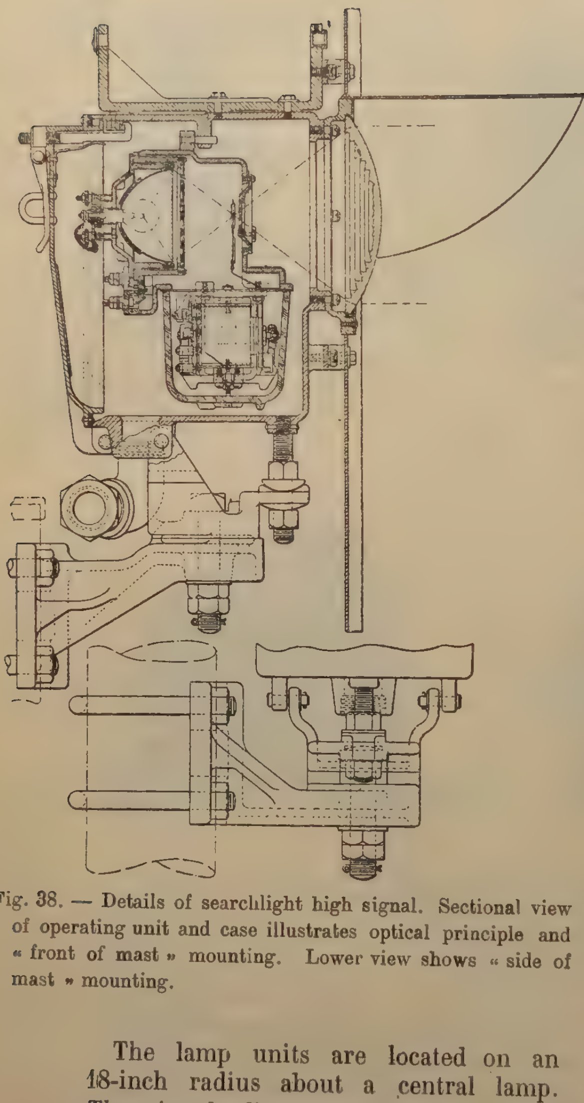


Fig. 38. — Details of searchlight high signal. Sectional view of operating unit and case illustrates optical principle and « front of mast » mounting. Lower view shows « side of mast » mounting.

The lamp units are located on an 18-inch radius about a central lamp. The wires leading to each lamp unit pass down through the 1 1/4-inch pipe supports, through the hub and a short piece of conduit into the terminal box. From the terminal box the wires lead into the signal mast through a flexible connection so that the signal unit may be aligned without disturbing the wiring, all parts of the unit being easily accessible. A sheet-iron background, attached to the pipe supports by means of substantial brackets, is used for the complete unit. These backgrounds are of two shapes, circular and oblong. The circular one is generally used on the top arm, while the bottom oblong one is used where it is only necessary to bring out one row of lights such as the vertical row on the approach restricting indication.

The lamp unit, figure 40, consists of a cast-iron case with a door on one or both sides, lamp, lamp receptacle, inverted lens, cover glass, mirror, mounting bracket and hood. The lamp has a concentrated filament, single contact bayonet base, the entire bulb being accurately-based similar to certain of the color light signals mentioned above. They are burned under their rated voltage to provide longer life, being rated at 12 volts and 6 candle power. The lamp receptacles are jig-set and cemented in place. This, with the accurately based lamps, permits renewing without affecting the adjustment. The lens is a 5 3/8-inch inverted toric lens of clear glass, and has a focal lengh of 2 1/4 inches.

The cover glass is conical in shape, of amber or slight yellowish tinted glass and has a frosted tip. The conical shape and frosted tip tends to prevent reflections of sunlight or sunglare and the tinted glass gives a more penetrating beam, especially under foggy weather conditions. Phantom indications are further prevented by applying black paint to a portion of the steps on the inside surface of the lens. The mirror is adjustably mounted and arranged to deflect some of the rays of light downward, thus insuring a good short range indication.

The mounting bracket is attached to the lamp case through a ball and socket

joint and by four bolts to permit of any adjustment that may be necessary to properly align the lamp. The other end of this bracket is attached to the 1 1/4-inch pipe post. The hood projects over the cover glass a sufficient distance to prevent the direct sun-rays from striking the cover glass to cut down the brilliancy of the unit as also mentioned under color light signals.

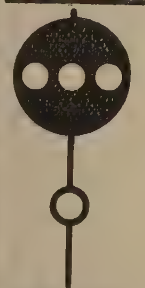
Only one lamp bulb is used in each unit. Should one lamp in any row burn out, there remains two other units lighted which still provide a satisfactory indication.

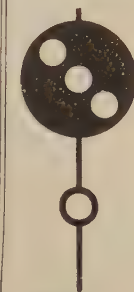
The position light dwarf signal is used for a short range indication and consists of a single cast-iron case with four openings for lenses. A door is placed on either side of the case to provide easy access to wire terminals and lamps. The case is about 15 1/2 inches high, 16 inches wide and 9 1/2 inches deep. The lenses are located on 8-inch center lines, radially from the pivot unit. On account of a short range only being required, no particular attempt is made to secure an accurate location of the lamp with respect to the lens. The lamp receptacle is bracket-mounted to the back of the case, is not jig-set, nor is the lamp rebased. The lamps used are of the concentrated single filament, single contact bayonet candelabra base type rated at 6 to 8 volts, 21 candle power and burned at 4.2 or 4.3 volts. The lens is 4 inches in diameter, of clear glass, and has its outer surface frosted to provide better diffusion of light as well as reduce sun-glare. This signal is ordinarily mounted at a slight angle, placing the front of the signal a little higher than the back. This throws the main rays from the signal slightly upward so that the engineman will obtain a better view on account of being considerably above the horizontal plane in which the dwarf signal is located.

Color position light signals.

The color position light signal is a combination of the two types of daylight signals previously described, in that colors as well as positions provide uniform day and night indications by means of two lights of the same color in a row. The signal, figure 34, consists of a main unit with marker lights above or below it to indicate whether the main or restricted route is set up; when a marker light above the main unit is lighted it indicates the main route is to be used, while an illuminated marker light below the main unit indicates the restricted speed route is to be used. There are sometimes two marker lights located above and below the main unit; the center of the vertical one is located about 4 ft 5 in. above or below the center of the main unit while the center of the other or staggered marker light is located 2 ft 4 in. from the center to the left of and in a horizontal line from the vertical marker light. No marker lights are used for aspects 1, and 16 to 18, figure 41.

The main unit consists of the desired number of lamp cases mounted on supports radially from the center, the units in each row being spaced 2 ft. 4 in. center to center. Each unit is constructed somewhat along the lines of the lamp or lens unit described under color light signals in that it has the doublet lens arrangement, the outer lens being of clear glass 8 3/8 inches in diameter, the inner lens being of the desired color. The marker light is of the same general construction. The lamp case is of cast aluminum and is bolted to the face plate of the

NAME.	INDICATION.	ASPECT.
275 Stop-Signal.	Stop.	
276 Stop-and Proceed-Signal.	Stop-Then proceed in accordance with rule 509 or 660.	
277 Grade-Signal.	For tonnage freight trains proceed not exceeding 15 miles per hour, expecting to find a train in the block, broken rail, obstruction or switch not properly set. For other trains, stop then proceed in accordance with rule 509.	

NAME.	INDICATION.	ASPECT.
282 Caution-Signal.	Approach next signal prepared to stop. Where a facing switch in connected with the signal, approach that switch prepared to stop. A train exceeding one-half its maximum authorized speed at point involved must at once reduce to not exceeding that speed.	
283 Approach-Signal.	Approach next signal prepared to stop. A train exceeding one-half its maximum authorized speed at point involved must at once reduce to not exceeding that speed.	
284 Approach-Restricting-Signal.	Train approach next signal at not exceeding one-half its maximum authorized speed at point involved but not exceeding 30 miles per hour.	

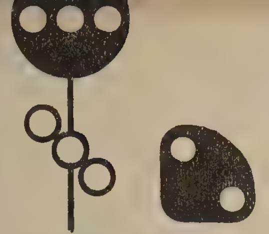
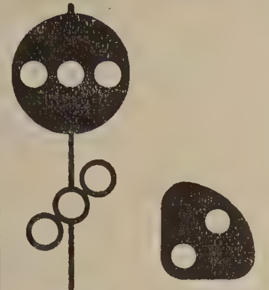
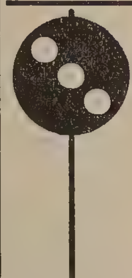
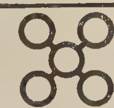
Caution-Slow Speed-Signal.	Proceed at not exceeding 15 miles per hour with caution prepared to stop short of train or obstruction.		Clear-Restricting-Signal.	Train proceed at not exceeding one-half its maximum authorized speed at point involved but not exceeding 30 miles per hour.	
279 Slow-Speed-Signal	Proceed at not exceeding 15 miles per hour prepared to stop at next signal.		286 Clear-Signal.	Proceed.	
280 Permissive Block-Signal.	For passenger trains stop and report in accordance with rule 362 or 462. For other trains proceed with caution prepared to stop short of train or obstruction.		287 Clear-Block-Signal.	Proceed-Manual or controlled manual block clear.	
281 Clear-Slow-Speed-Signal.	Proceed at not exceeding 15 miles per hour.		288 Take-Siding-Indicator.	Take siding.	

Fig. 39. — Aspects and indications for position light signals, Pennsylvania Railroad.

(Grade signal designated by letter "G,, on yellow background).

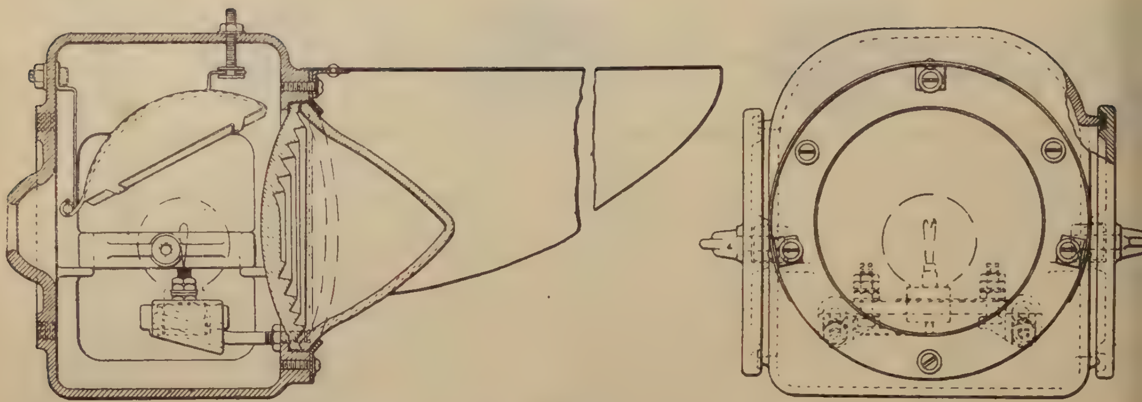


Fig. 40. — Lamp unit for position light signal.

signal. The lamps used are 13 1/2 volt, 17 watt, equipped with single contact bayonet candelabra base.

One of the outstanding features with this system is the fact that when a Proceed indication for any route is displayed there are no Red lights appearing on the signal and the same indications can be given on dwarf as on high signals.

Usually one unit of each row of units is supplied with a transformer with suitable taps to provide close adjustment of the lamp voltage. The standard transformers have a capacity of 40 volt-amperes at 60 cycles. One transformer is used for the two red lamps, one for the two yellow, etc.

The dwarf signal used in this system is a compact miniature high signal contained in a metal case 2 ft. 9 1/2 in. high and 17 1/2 inches wide, resting on a base 24 inches wide and 8 inches deep. The units in each row are spaced 11 1/2 inch centers. The outer lenses in the dwarf signals are clear glass 3 1/2 inches in diameter, the colored lenses being on the inside as in the high signals. The lamp is the same as that used in the high signals.

Cab signals.

In principle the design of cab signals has followed very closely that of daylight signals except, of course, in miniature. As indicated in figure 42, there are three distinct types of cab signals commonly used. These are, two indications, red and green lights; three indications, red, yellow and green lights, also L. M. & H. for low, medium and high speeds; four indications, red, yellow, yellow over green, and green lights. Cab signals having position light aspects have been made extensively for both three and four indications. It is becoming customary to place cab signals on both the engineer's and fireman's sides of the cab.

The lamps used in the cab signals are of the screw base 32 volt, 15 watt type being placed behind ground glass roundels of the proper color.

Color light signals in the British Empire.

During the last few years there has been an increasing tendency to use daylight signals of the color light type in

the British Empire. Signals having three vertical lights find more universal application, although there are some installations using two light units, red and green or yellow and green. One combination which appears to be used exclusively in Great Britain, is the four-light signal illustrated in figure 43. Where there is ample vertical clearance, the vertical assembly of lamp units is used, but for bridge mounting or where there is restricted head room the radial assembly of lamps is used as indicated in figure 44. The four aspect signal is fitted with one red, one green, and two yellow lights. The double yellow aspect denotes to the driver of a high speed train or non-continuous-braked train that he is within braking distance of a danger signal, while the single yellow aspect denotes the same to a driver of a low speed or continuous-braked train.

Another type of color light signal frequently used is a fog repeater signal. This type is illustrated in figure 45, and is usually of the two unit light type.

In order that the driver may have knowledge of the route over which he has received a caution or proceed signal, some English Railroads have used a supplementary optical route indicator, one of these is illustrated in figure 19, and from the line drawing figure 46 it will be seen that as many projectors as there are numbers, are mounted on a radial supporting plate so that the light rays from each will project respective numbers on the front screen. Moving parts are eliminated in this type of signal.

Signal aspects in England are seldom the same on different railways, except that the colors, red, yellow and green predominate. These colors in combination and with marker lights provide the necessary indications. Lamp voltages vary to suit local conditions, however, there appears to be a preference for the use of 12 volt, 24 watt double filament lamps. For the shorter range signals a « stand by » or auxiliary lamp is sometimes used.

In Australia and New Zealand the three vertical light type of color light signal is commonly used for both automatic block and interlocking applications. Red, yellow and green are the prevailing colors. Some of the lamps used are 12 v.-24 w.; 12 to 14 v.-36 w.; and 8 to 16 v.-18 w., usually of the double filament type. The New South Wales Government Railways use two 2-aspect light signals to provide three indications; yellow lenses are not employed.

In India the design of color light signals follows generally that of English practice. Two aspect signals provided with red and green lenses predominate. Two of these signals are sometimes mounted one above the other to display red over red for Stop; green over red for Proceed with caution; and green over green for two or more blocks clear. 12 v.-24 w. double filament lamps are generally used.

Recent installations in South Africa have been equipped with color light signals of the usual three aspect vertically aligned type for main line moves. Position light signals are used for shunt or secondary moves and are one position when mounted on a pole with a three position color light signal, as in illustration (fig. 23), and two position when located alone on the ground, as shown in figure 47. Lamps are of the 12 v.-24 w. type. Projector type route indicators are used in connection with the « up » home signals at interlockings.

Color light signals which are being used in South America are of the vertically aligned three aspect type using 10 v.-18 w. or 30 w. lamps. In Japan exten-

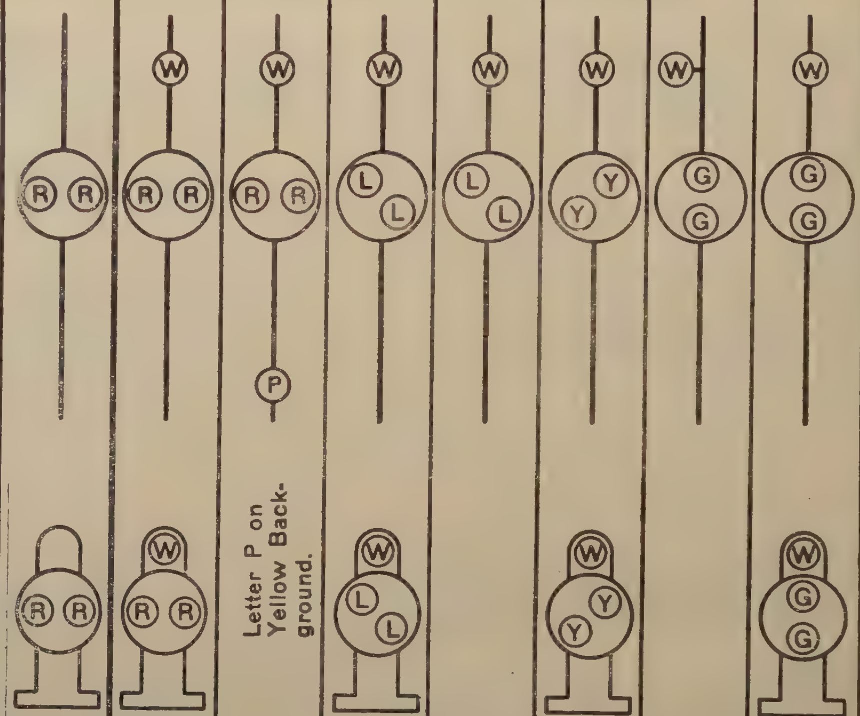
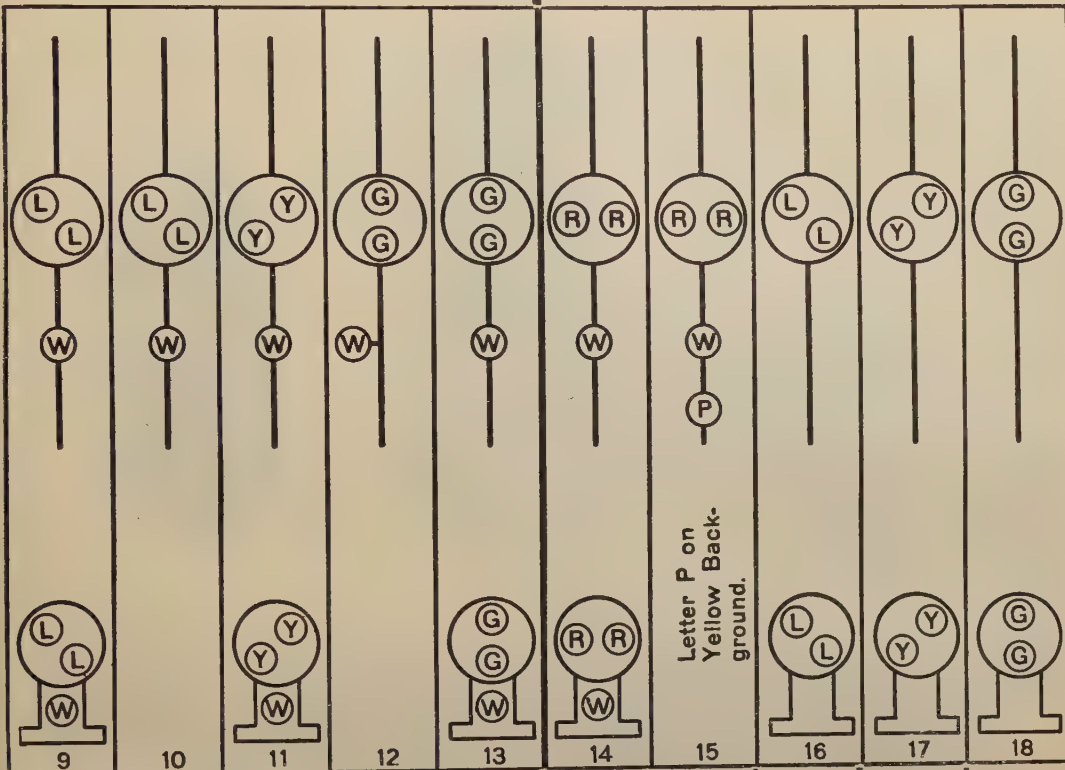
—	ALL ROUTES	NORMAL ROUTES.						
DAY AND NIGHT ASPECTS.								
	1	2	3	4	5	6	7	8
NAME and CALL.	Stop.	Stop and proceed.	Grade.	Restricting.	Permissive	Approach.	Approach medium.	Clear.
INDICATION.	Stop.	Stop then proceed in accordance with rule 509 B	For tonnage freight trains proceed not exceeding 15 miles per hour excepting to find train in block, broken rail, obstruction, or switch not properly set. For other trains, stop then proceed in accordance with rule 509 B.	Proceed at restricted speed.	Block occupied, proceed prepared to stop short of train ahead. Apply in manual block territory only.	Prepare to stop at next signal. Train exceeding medium speed must at once reduce to that speed.	Approach next signal at not exceeding medium speed.	Proceed.

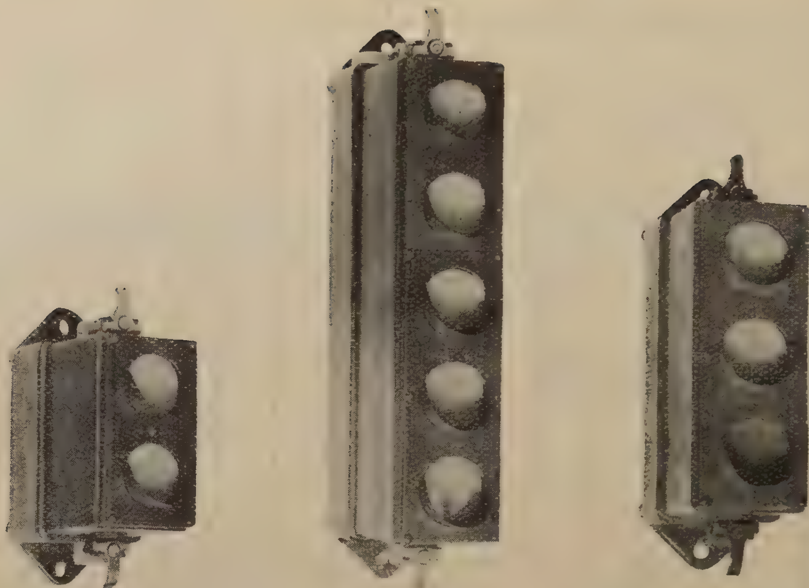
Fig. 41. — Aspects and indications — Color-position

MEDIUM ROUTES.					SLOW ROUTES.				



MEDIUM ROUTES.	9	Restricting.	Proceed at restricted speed.
	10	Permissive.	Block occupied, proceed prepared to stop short of train ahead. Apply in manual block territory only.
	11	Approach.	Proceed at not exceeding medium speed prepared to stop at next signal.
	12	Approach medium	Proceed at not exceeding medium speed. Approach next signal at not exceeding medium speed.
	13	Clear.	Proceed at not exceeding medium speed.
SLOW ROUTES.	14	Stop and proceed.	Stop then proceed in accordance with rule 509B.
	15	Grade.	For tonnage freight trains proceed not exceeding 15 miles per hour excepting to find train in block, broken rail, obstruction, or switch not properly set. For other trains, stop then proceed in accordance with rule 509B.
	16	Restricting.	Proceed at restricted speed.
	17	Approach.	Proceed at not exceeding slow speed prepared to stop at next signal.
	18	Clear.	Proceed at not exceeding slow speed.

light signals. — Baltimore & Ohio Railroad.



2-aspect cab signal. 4-aspect cab signal. 3-aspect cab signal.

3-aspect cab signal in locomotive.

Fig. 42.

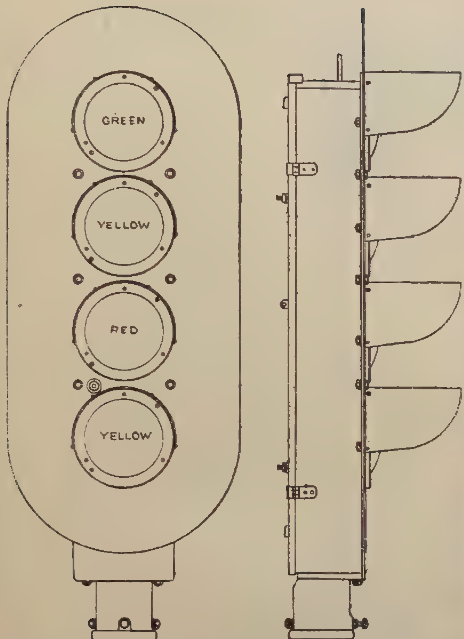


Fig. 43. — Four-light color light signal (vertical assembly).

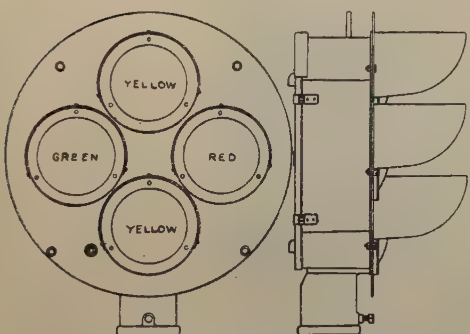


Fig. 44. — Four-light color light signal (radial assembly).

sive use is made of two and three aspect color light signals, the former for electric lines using light cars, the latter for high speed steam or electric traffic where braking distances are greater. Both 10 v.-30 w. and 30 v.-40 w. lamps are

Fig. 45. — Fog signal, England.

used. Color light sigals in South Manchuria are of the 3-aspect type.

United States and Canada.

Automatic block system.

Of the 58 000 miles of road of automatic block signals in the United States and Canada, 30 500 miles are installed on single track lines. Two systems of signaling are generally provided for single track automatic block signals; the overlap and absolute permissive block (APB) systems. The earlier overlap system provided head-on signal protection for opposing train movements only between adjacent signals, depending upon the train order or manual block system for regulating the meets at passing signals, whereas with the APB system op-

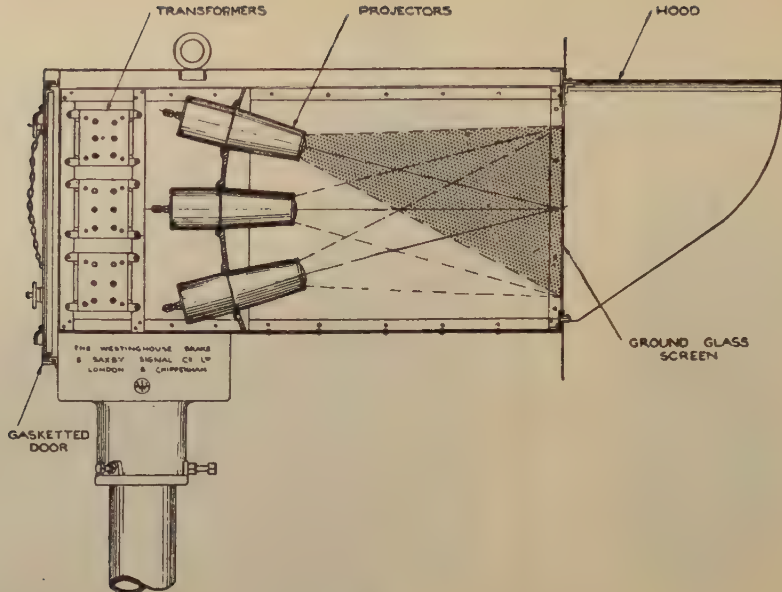


Fig. 46. — Optical route indicator.

Fig. 47. — Position light dwarf signals, South African Railways.

posing train movements are blocked from one passing siding to another. Under normal train operation, either system functions as intended to increase the safety and facilitate train operation, but in case of a train finding a signal at its most restrictive position, the rules under each system are entirely different. With the overlap system, a train usually only proceeds when preceded by a flagman as the signal may be indicating that there is an opposing train in the block. With an intermediate automatic signal in an APB system at its most restrictive position, the rules generally provide that the train can proceed within range of vision as the system is so designed that an opposing train is held at the next passing siding. In case the entering or absolute signal is at « Stop », the rules provide for the train crew to call the dispatcher on the telephone and obtain special instructions for passing the « Stop » signal. The delays in an overlap system due to the flagman walking shead of the train for one or more blocks, are sometimes serious to train operation, and this is one of the reasons why the newer installations are of the APB type. The latter type is also of advantage in providing a more flexible system of indications for switching movements around yards as the « Stop » signals can be located outside the yard limit territory. Where formerly automatic signals were feft outside of yard territory, some roads are now installing automatic signals in yard territory using dwarf signals in place of high signals where track clearances are restricted, in order to secure additional protection for slow speed yard movements and to speed up the high speed traffic. Generally the absolute signal at the end of a passing siding was located beyond the switch but in recent years many roads have located the signals at the fouling point of the switch, using a second signal to provide train movements off the siding. With such a signal arrangement, power operation of the switch can be substituted for hand operation at a minimum expense, and trains moved into and out of the siding by signal indication without train orders.

During recent years there has been a great increase in the number of remotely controlled power switches, particularly at the ends of passing sidings on grades where considerable delay and trouble occured under hand operation of the switches. While many of these remote control switches are at scattered points on a division, the Baltimore & Ohio Railroad is now operating a 102 road mile main line division, of which 89 miles is single track and 13 miles is double track on which the ends of double track and all passing siding inlets and outlets are interlocked and controlled from three mechanical interlocking plants and sixteen table lever interlocking machines located in the block stations, there being 10 mechanically operated interlocked derails, 22 mechanically operated interlocked switches, 56 remotely controlled électrically operated interlocked switches, 209 color position light high signals and 79 color position light dwarf signals. The ruling grades in this territory vary fom 0.96 % to 1.47 % while there are 23 tunnels in this section ranging in length from 300 to 2 710 feet. Where formerly trains were operated by manual block, train orders, and hand throw switches, under the new operation trains of every class are being operated by signal indications without train orders or superiority by right or class or time table instructions. The automatic signals are spaced from 5 000 to 6 000 feet apart between opposing

head block signals to insure proper spacing of following trains. The automatic signals are controlled on the APB principle except that special circuits are provided for control of the « Stop and Proceed » indication, the arrangement being such that for following train movements, one train following another into an occupied block, a « Stop and Proceed » indication is displayed, while for opposing train movements on the entire single track section, a « Stop » indication is displayed. Trains receiving a « Stop and Proceed » indication are governed the same as in double track territory while the « Stop » signals cannot be passed except by order of the dispatcher, or, when preceded by a flagman a sufficient distance to insure protection. The electric switches and signals are controlled by table lever interlockings, a 7 lever unit being required at a single passing siding and a 12 lever unit for a double passing siding, each interlocking being equipped with switch, signal and traffic levers. Signal levers are normal in the central position and operate to left for trains in one direction and to right for trains in the opposite direction. Short traffic levers precede the clearing of signals which govern within passing siding limits. These are equipped with an electric lock arranged to lock the lever in either the normal or reverse position. The reversal of a signal lever governing trains in one direction locks the short traffic lever normal, while the reversal of a signal lever governing over the same track in the opposite direction locks this lever reversed. Long traffic levers govern trains over the single track section from the outlet at one station to the inlet at the next station and are electrically locked in the normal position only. These levers precede the clearing of the head block signal and must be unlocked by the operator at the next station. They are also controlled through the track circuits and, therefore, cannot be unlocked unless the opposing head block signals are at « Stop », all track circuits between the sidings unoccupied and the traffic lever at the next tower in the normal position. The dwarf color position light signals govern movements from the siding to main track or siding to siding and convey the same information to trains leaving a siding that is provided for main track movements, except that a clear indication is not given although means is provided to convey the same number of aspects that are provided by the high signals. Train movements are governed by the dispatcher, who upon being informed a train is approaching a station, directs the operator to allow it to proceed on the main track or to take siding, and in this way trains frequently pass without either being stopped. The operating results indicate that train delays have been reduced, train speeds increased, track capacity increased, safety of train operation increased, train tonnage increased, trains kept moving at closer intervals, train stops avoided through the issuance of orders, materially reducing the number of train hours at a minimum capital expenditure for new facilities. This installation, while of longer length, is only one of several which have been installed on many roads in the past few years.

Probably the most recent development in the signal field in the United States in the past few years, which is attracting the attention of railwaymen, is the dispatcher controlled signal system, whereby the control of all passing siding switches and signals on a specified territory are centralized in the office of one dis-

Fig. 48. — Color position light automatic signaling on Baltimore and Ohio Railroad.

Fig. 49. — Position light automatic signaling on Pennsylvania Railroad.

patcher, eliminating the local operator control at the various block offices. While this system is applicable to two or more tracks as well as to single track, the first installations have been on a 40 mile section and a 20 mile section of single track road, although some double track sections are now being installed. In this system, the usual automatic block signals are used between sidings and the standard interlocking signals and switches are used at the sidings, the switches being generally of the 20 volt direct current type operated from storage batteries, although some electro-pneumatic switches have been installed, while the signals are of the light type. The electric switches operate from one position to another in 5 to 13 seconds, depending upon the weight of rail and other local conditions. The control panel located in the dispatcher's office is equipped with an illuminated track model for visually indicating the train movements at the ends of the passing siding, the necessary switch and signal levers, although in some cases a combined lever is used, and a visual train-graph upon which is either manually or automatically « OS » ed the time a train passes each end of siding location. Thus the dispatcher has before him a graphic record of every train move made in the controlled territory and he can tell whether a train is losing time, running on time or making up time, because the train either automatically « OS » es on the graph sheet as it proceeds over the division or is manually « OS » ed by the dispatcher as the visual indications are obtained on the illuminated track model. This information gives the dispatcher the equivalent of three trick operation at all points in the controlled territory, so that he is not confronted with the situation, oftentimes occurring under other methods of operation, where trains are « lost » for a considerable period of time while running past one or two, and at night often more, unattended block stations. If there is likely to be a considerable amount of switching necessary at a location equipped with a power switch, a dual control mechanism provides for power operation of the switch in the usual manner, but may be operated by hand by the train crew upon instructions from the dispatcher. In this case, the train crew desiring to operate the switch by hand, unlocks a selector lever, a lever similar to the hand throw lever of the ordinary switch stand, which after being thrown, cuts the power off the switch mechanism and sets the signals at « Stop » and leaves the switch free to be thrown by the usual hand throw lever. After hand operation is completed, the selector lever is returned to its normal position, thus returning both the signals and the switch mechanism to the control of the dispatcher. The dispatcher controlled signal system employs the usual detector or switch locking circuits which insures that a switch cannot be moved by the dispatcher if a train is on the « fouling » circuit. In addition, approach locking circuits are provided to prevent the dispatcher taking the signal away and reversing the switch ahead or an approaching train. If, for some emergency reason, it is necessary that the dispatcher change the route ahead of a train, he places the signals at « Stop », then to change the position of the switch, the train must stop and obtain telephone instructions to push a release, located near the switch, which will release the approach locking and permit of the switch being operated by the dispatcher, or, as now being installed on some of the more recent installations, the dispatcher can operate a time release and

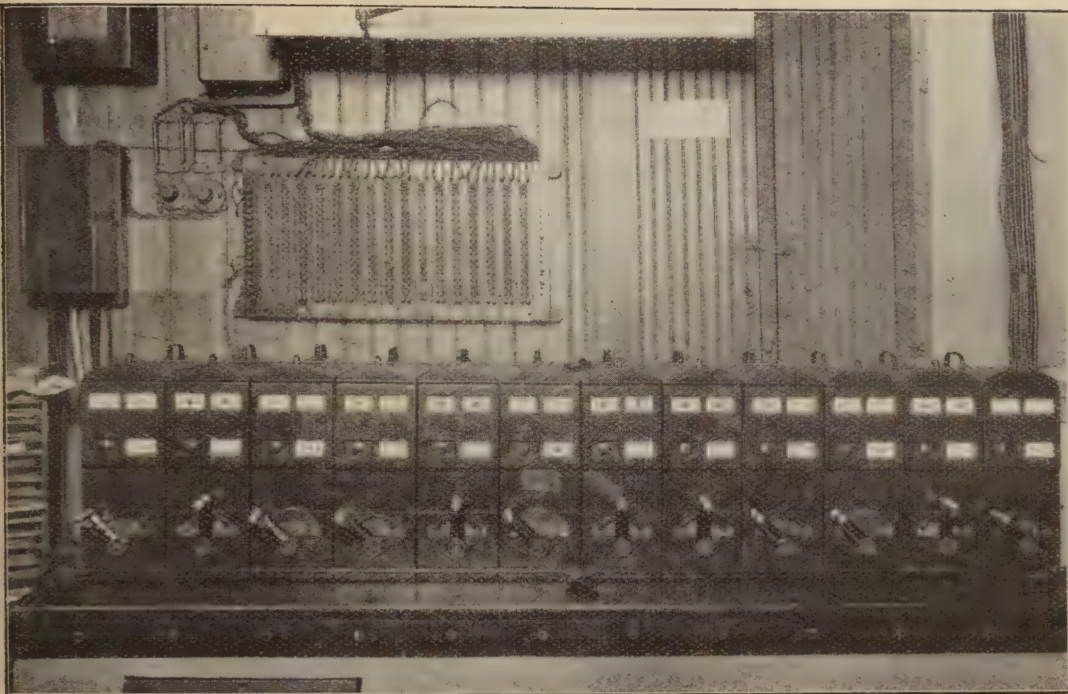


Fig. 50. — Table interlocker of 12 levers for controlling 2 passing sidings on Baltimore & Ohio Railroad.

Fig. 51. — Remote control siding location with signal on Baltimore & Ohio Railroad.

Control panel

Passing siding.

Dual control switch operating mechanism.

Fig. 52. — Dispatcher control signaling system on Pere Marquette Railway.

Fig. 53. — Automatic block signals of the color light type on Canadian National Railways.

obtain automatic release of the approach locking circuits without any action on the part of the train approaching the « stop » signals. A telephone is located at each end of a passing siding and also at switches where a train can clear the main line so that instructions can be given to work trains, for switching movements and for other emergency purposes.

There are three methods of directing the movements of trains on the railroads of the United States and Canada — by timetable and train orders, by timetable, train orders and block signals, and by signal indications. In the first two methods, the train order plays the leading part, particularly in directing train movements on single track. One estimate shows that the 5 000 train dispatchers issue no less than 130 000 train orders daily or close to fifty million train orders annually for directing train movements. Since 1882, the single track on the Louisville Bridge of the Pennsylvania Railroad has been operating trains by signal indications in lieu of train orders and time table superiorities until now there are over 167 installations on 41 roads, of which 819.4 miles are on single track, 583.6 miles on double track, 168.2 miles on three track, and 76.9 miles on four track road, a total of about 2 250 miles of track, and new installations on several hundred miles are now under way. These installations have been made on account of the operating benefits derived from the signal indication methad of directing train movements resulting in reducing train delays, increasing track capacity, reducing freight train operating costs and increasing safety of train operation by the more intensive use of

existing track facilities by means of modern signaling.

One of the interesting developments of the train control installations in the United States has been the adoption by twenty-two roads of the continuous cab signal system on some 7 250 miles of track and 4 100 locomotives, and electrically propelled cars with all signal aspects displayed in the cab before the engineman or motorman. While three of the roads are operating some 1 750 miles of track and 700 locomotives on single and double track without wayside automatic block signals, except at « Stop » locations, the general practice is to supplement the existing automatic block signaling with continuous cab signals. Cab signals continuously controlled and constantly visible, have formed an intimate part of the continuous system of train control, and have shown so many operating advantages and elements of increased safety that their use, without the addition of the automatic brake control, is now meriting serious consideration, and the Pennsylvania Railroad is now installing about 700 track miles of cab signals between New York and Washington which will be of the universal interchangeable coder type and so arranged that a whistle will blow when a change is made to a more restrictive cab indication, so that the fireman as well as the engineer will be visually and audibly informed of the change of track conditions. The report of the Interstate Commerce Commission of 26 November, 1928, contains this statement about cab signals :

Cab signals are without a doubt an important development in the art of signaling. They place the signal indication immediately in front of the engineman where it cannot be obscured by snow, fog, smoke or other obstructions, and where a combination of visible and audible indication is used it is, without a doubt, a valuable addition to the signal system.

A considerable increase has been made in the number of railroad crossings at grade equipped with automatic signal protection which eliminates the necessity for an ordinary interlocking and attendants for operation of the levers. Where, a few years ago, only a few such installations were in service, today there are a few hundred locations, 40 of which were installed on 24 roads in 1928, and 65 more were contemplated in 1929. Automatic signal protection of this type is proving of operating benefit due to the speeding up of train movements at unprotected crossings where train stops are now eliminated, and the economy due to the operators dispensed with in the new signaling.

During recent years several hundred spring switch installations have been made not only in automatic block, but also in train order and manual block territory, usually at yards, end of passing sidings and end of double track locations. The simpler installations comprise the substitution of a spring switch mechanism with an oil buffer arrangement for the usual handthrow switch with a signal for protection against an open or misplaced switch in the facing point position, trailing movements sometimes being made without a signal except the ordinary switch stand marker and lamp. At spring switch locations the speeds of all trains are usually restricted over the normal speed specified at hand throw switch locations, but due to the fact that train stops are saved in one direction of traffic, the speed restriction are of minor consideration.

The general practice on the railroads of the United States and Canada is to prepare an economic and operating report of the signal expendidure under the present method of train operation as compared with that under the proposed signal facilities in order to insure that the new signaling will be economically justified. While the older installations of automatic block signals and inter-locking plants were generally installed for increased safety, the present day tendency is to only approve those authorities for new work which show some return upon the investment, the principles for such studies being outlined by the various Committees in the Sections and Divisions of the American Railway Association.

SUMMARY.

On account of the large railroad mileage, it is not surprising that the United States and Canada lead all the other countries in the amount of automatic block signals. The longer spacing between towers, block offices and stations, the rising cost of labor and the necessity for handling increasing traffic safely and quickly, are important factors in the greater mileage of automatic block signals in these two countries. It is interesting to note the large mileage of automatic block signals in Japan and China and that light signals are so generally used. The automatic block signaling in all of the other countries, except New Zealand and New South Wales, appears to have been necessary for fast traffic zones in suburban territory approaching terminals and main stations, as in Buenos Ayres, London and Capetwon. Formerly some of the heavy traffic lines in the United States only installed automatic signals on double or multiple track lines, but now extensive signaling of single track lines is being undertaken even on lines of light traffic. The British system of signaling is based upon the general use of the absolute block, while in the United States and Canada this type of block system is only used on a short mileage as compared with the large mileage of permissive block signaling.

The general use of automatic train control devices, outside of the London underground and similar tube, subway and elevated installations in the different countries, has been entirely in the United States. The early installations, of some length, were the result of the First Order of the Interstate Commerce Commission of the United States Government issued in 1922, and a Second Order issued in 1924, the two orders amounting to 15 163.3 miles of track while voluntary installations of over 5 000 miles of track have been made and additional mileage of the continuous coder cab signal system but without the brake applying apparatus, is now being installed. All of these installations are based upon the use of continuous track circuits as distinguished from the non-track circuit mechanical devices as installed in Great Britain.

The use of grade signals in automatic block signal territory so as to permit trains to pass an automatic signal into an occupied block without stopping is the general practice only in the United States. Japan and China. The use of heavier locomotives and increased train loading, amounting to 7 000 to 10 000 tons per train of 110 to 130 cars, is a growing practice on the railroads of the United States and Canada and the stopping, as well as the starting, of such trains is a more serious problem in these countries than is the case when shorter trains and lighter loading is the general practice.

While the color light signal is the ge-

neral standard in the United States, the British Empire, Japan and China, there is a large mileage of position light and color position light signals in the United States, while in Africa and Japan the shunt or slow speed signals are of the position light type. While two aspect light signals are used in several countries where the older semaphore signaling is of the two position lower quadrant type, the majority of the new signaling has been of the three aspect type, although the four aspect type has been used on the shorter block lengths in the United States and Great Britain for three block indication purposes. The signal names and indications are generally the same in all the countries, Red indicating « Stop », Yellow indicating « Caution » or « Approach » and Green indicating « Proceed ». The four aspect system used in Great Britain requiring two Yellow lights compares to the Yellow over Green indication as used in the United States. In Great Britain and Africa, a light indicator is used in connection with the light signal to designate a route or platform, although such practice never has been used in the United States. Generally the British system of signaling gives more information to the driver of the train while in the United States and Canada the signaling is based upon speed. The adoption of light signals in place of semaphore signals in the United States and Canada has been due to the following additional advantages of the light type not mentioned in the report on the British practice.

1. On account of the elimination of many parts, except relays, the chances of failures are reduced.
2. Semaphore aspects are usually limited to three while with light signals four or more aspects may be provided.
3. Can be used in more restricted clearances.
4. The first cost of light signals is less than for other types providing an equivalent number of aspects.
5. The cost of power for operation is usually less.
6. Requires a smaller number of repair and renewal parts to be carried in stores department stock .
7. Permits the use of the same aspects on dwarf as on high signals.

The American Railway Association Signal Section requisites for light signals, as adopted in 1921, are as follows :

1. They shall be free from the possibility of phantom indications.
2. When lamps are operated at normal voltage, the range (on tangent) of signals used to govern high speed trains, must be at least 2 500 feet on a clear day with a bright sun at or near the Zenith.
3. They shall not be so bright as to cause confusion in reading signals at night.
4. Normally a beam spread of not less than three degrees each side and below the axial beam shall be provided. Means shall be provided for increasing the beam spread on either side to suit special conditions.
5. Means must be provided to give a distinct indication to enginemen when approaching and or stopped at the signal.

While these requisites permit a range of at least 2 500 feet, one road requires a minimum range of 4 000 feet on high signals and 500 feet on dwarf signals. One interesting result of the adoption of light signals has been the increasing use of improved lighting in semaphore signals brought about by the complaints of the

enginemen relative to the unfavorable comparison of oil lighted signals as compared with light signals. Such complaints have been particularly noticeable where light signals adjoin the older type of signal on the same operating division and resulting in the general substitution of electric lighting for oil lighting on signals and often on switch lights.

The interlocking practice in main stations and terminals is practically the same in all the countries except that more power interlockings are used in the United States than in the other countries. There is a tendency to substitute power operation for hand operation by combining several small mechanical plants into larger power plants as conditions warrant the change not only in the United States, Canada and Great Britain but also in Africa. The largest plants are of the electro-pneumatic type, although all-electric machines of the A. C. or D. C. type are used in some of the countries, the machines being equipped with every facility for providing safe and efficient train operation.

A greater amount of reverse traffic or either direction signaling has been installed in the United States than in any of the other countries although this type of signaling has been installed on short sections of track in several of the countries. The extensive use of remotely controlled switches and signals, as well as the new system of dispatcher control, appears to be a development only in the United States and Canada.

While data is not available to show the yearly expenditures for signaling in all the countries included in this report, it may be of interest to quote the figures for the United States for two different years. The annual reports of the Interstate Commerce Commission for the years 1923 and 1927 show the following signal statistics :

	1923 (dollars)	1927 (dollars)
Maintenance of signals and interlockers . .	26 037 386	32 847 323
Operation of signals and interlockers . . .	25 454 221	26 153 282
Investment in road and equipment	10 807 839	32 203 889
Total	62 299 446	91 204 494

These totals do not include signal charges on account of crossing protection, telegraph and telephone lines, joint yards and terminals, yard supplies and expenses, tools, etc.

The expenditure of such a large sum annually for railway signaling in only one country naturally calls for every possible economy and it is of interest to note that in several of the countries there is a growing tendency to base signal improvements upon economic studies in order that train operation can be expedited and the safety of train operation increased at a minimum outlay for installation, maintenance and operation.

[621. 132. 8 & 656 .22]

REPORT No. 1

(America, the British Empire, China and Japan)

ON THE QUESTION OF ECONOMICAL TRACTION METHODS FOR USE IN PARTICULAR CASES (SUBJECT XII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By R. H. NICHOLLS,

SUPERINTENDENT OF THE LINE, GREAT WESTERN RAILWAY (GREAT BRITAIN).

Figs. 1 to 17, pp. 1871 to 1885.

A. — Organisation of train services on the minor lines of the large systems carrying little traffic and of little used trains on the more important lines of these systems.

The Canadian National Railways report that :

On their system there are numerous lines where traffic is relatively light and this has led to the consideration of the possibilities of the self propelled type of passenger equipment which offers the advantages of a reduction in the size of the train crews, relatively low maintenance expense and greater availability than can regularly be obtained from steam locomotives. Between 1921 and 1923, 6 storage-battery cars were introduced, which are only suitable for very short runs. In 1925, 9 oil-electric cars were introduced; these are equipped with light weight Diesel engines driving through an electric transmission system. The character of the lines on which these cars operate varies from flat prairie country where grades are relatively low, to lines with as high a gradient as 2 % with a maximum length of three miles. The experience with these cars and their ability to convert an operating deficit or extremely small margin of net return into an appreciable net operating revenue on light passenger traffic runs led to the building of five more oil-electric cars in 1927. While in detail, of essentially the same construction as those in the former cars, they are of the six cylinder type, whereas the engines in the earlier cars are equipped with four and eight cylinders respectively. Where traffic is very light the Canadian National has also in use 4 gasoline-electric cars, introduced between 1926 and 1928, and it is probable that this type of car will replace the storage-battery cars in the future.

It is contemplated that the use of the oil-electric cars will be extended in the

(1) This question runs as follows : « *Economical traction methods for use in particular cases, as for example :*

A) Organisation of train services on the minor lines of the large systems carrying little traffic, and of little used trains on the more important lines of these systems.

B) Use of special tractors for shunting in smaller yards and for certain work in large yards ».

future and the gasoline-electric to a lesser degree (figs. 1, 2 and 3).

The South African Railways report that :

On their lines the only motor vehicles are a Sentinel steam car, and a few petrol driven vehicles which are used in experimental services. So far, none of them has given such satisfactory results as to justify being employed permanently on regular services. There are branch or minor lines on the South African Railways varying from 3 miles to over 300 miles in length worked by steam locomotives, varying in haulage power principally according to the strength of the tracks. The 2-foot lines are laid with 20-lb., 30-lb., 35-lb., or 45-lb. rails; while the 3 ft.-6 in. minor lines are laid with 35-lb., 45-lb., or 60-lb. rails.

Engines of the Garratt type are employed in some instances on the 2-foot and 3 ft.-6 in. lines, their maximum loads and the maximum loads of the ordinary steam engines more generally employed on these lines being governed as already stated by the weight of the track as well as by the gradients, curvature, bridges, etc.

The train service on the minor lines of this Administration varies from a tri-weekly one to a daily or more frequent service according to the volume of traffic usually offering and to seasonal conditions. On most of the minor lines the train service is a mixed one, i. e., the train conveys both passenger and goods traffic. On certain trains in addition to goods vehicles, one passenger coach is run, namely, a composite carriage with compartments for 1st and 2nd class European passengers and 3rd class native passengers. On other trains three coaches may be run, in addition to goods wagons, viz., two for 1st and 2nd class European passengers, with separate compartments for 1st and 2nd class coloured passengers and the other coach for 3rd class native passengers.

On minor lines, guards collect passengers' tickets and also issue tickets to those passengers joining at sidings, halts, etc., where it is not necessary to employ a station staff.

The Great Northern Railway of Ireland report that :

There is no method of traction other than ordinary steam locomotives and carriages at present employed on their system. A certain number of passenger trains especially in cases where the time available at terminals is not sufficient to permit of the engines being run round, are worked by a tank engine and one to four carriages as required as shown in figure 4. The opening of the engine regulator is done on every occasion by the men on the footplate but when running in the reverse direction with the engine in rear, the driver riding in the compartment at the front of the train has complete control of the regulator and the application of the continuous brake.

The London Midland and Scottish Railway report that :

Sentinel Cammell steam rail coaches have been introduced to cope with the passenger traffic on the minor lines and 13 of these vehicles were put in service in 1927. These steam rail coaches are self contained vehicles and are not designed to handle more than one additional light weight vehicle. They consist of a power unit, carrying a « Sentinel » engine and boiler on a four wheeled bogie, both axles of which are chain driven, connected with the carriage body by an

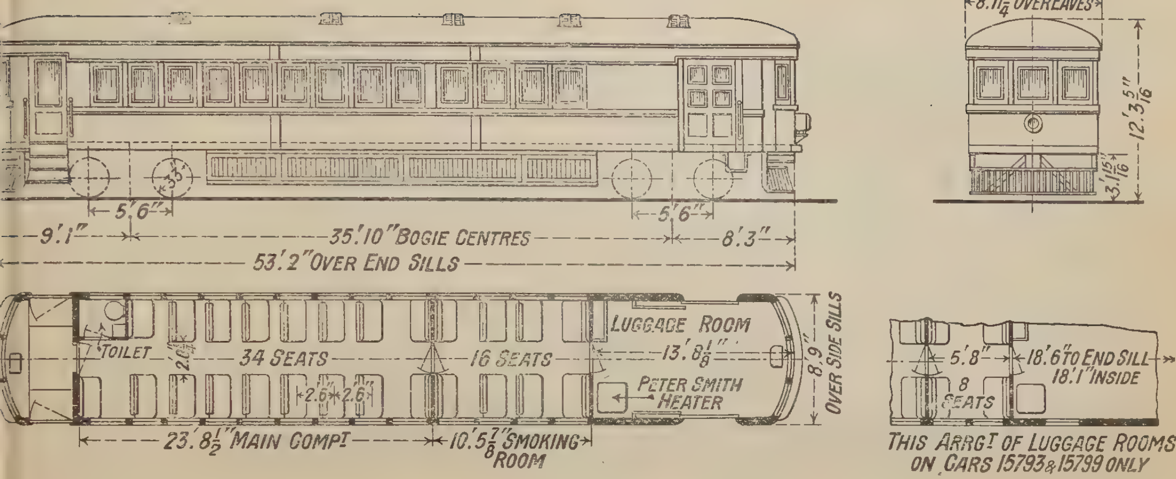


Fig. 1.

Cars Nos. 15795, 15796, 15798, 15799. Storage battery coach.

ate built	1924.
uilder	Canadian Car and Foundry Co.
ength :	
over bumpers	53 ft. 9 11/16 in.
» end sills	53 ft. 2 in.
» main compartment.	23 ft. 8 1/2 in.
» smoker	see diagram.
» luggage compartment	see diagram.
» milk	none.
idth over side sills	8 ft. 9 in.
eight :	
inside	8 ft. 2 13/16 in.
from rail to roof	12 ft. 3 5/16 in.
eating capacity :	
main compartment	34.
smoker	see diagram.
luggage	none.
eight	73 800 lb.
yle :	
of body	steel frame.
of vestibule	enclosed, trap door.
of doors : passenger compartment	anti pinch hinge.
luggage	roller slide.
indows :	
number	see diagram.
size	24 × 31-inch glass.
style	ratchet stop.
ats : size	3 ft. 2 in. overall.
pholstery	rattan.
ogie	4-wheel.
heel base	5 ft. 6 in.
otal wheel base.	41 ft. 4 in.

Axles :	
size	3 3/4 inch. for roller bearings.
material	steel.
Wheels	steel tyred.
diameter	33 inches.
Springs	double elliptic.
size	30-inch. crs.
Brake equipment	Westinghouse, A. M. M.
Air compressors	Westinghouse, type D. H. 16.
Motor	General Electric 261-A.
Controller	General Electric, type K.-40-B.
Lighting and generating system	none.
Battery :	
style	Edison A.-12-H.
number of cells	250.
Headlight	Golden glow, type E. F.-128.
Horn or whistle	Westinghouse whistle.
Bell	Dayton pneumatic.
Signal system.	Bell cord.
Couplers :	M. C. B. 9 1/4-inch. head, 5 × 5-inch. shank, 6 1/2-inch. end, bottom operated.
Sanders	Ohio Brass.
Heating	Peter Smith heater, type No.15.
Lavatory	No. 22 Rex dry hopper.
Type of axle bearing	S. K. F. spherical self aligning roller bearing No. 22 322 with adaptor sleeve.

Miscellaneous : 1 motor and gear weighs 1000 lb.

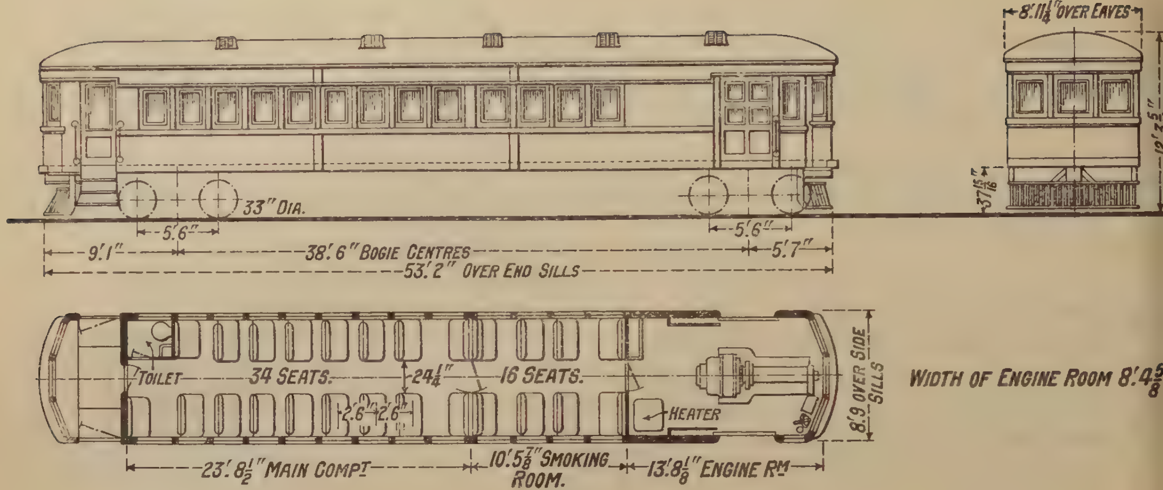


Fig. 2.

Cars Nos. 15794 and 15797. Gas electric car.

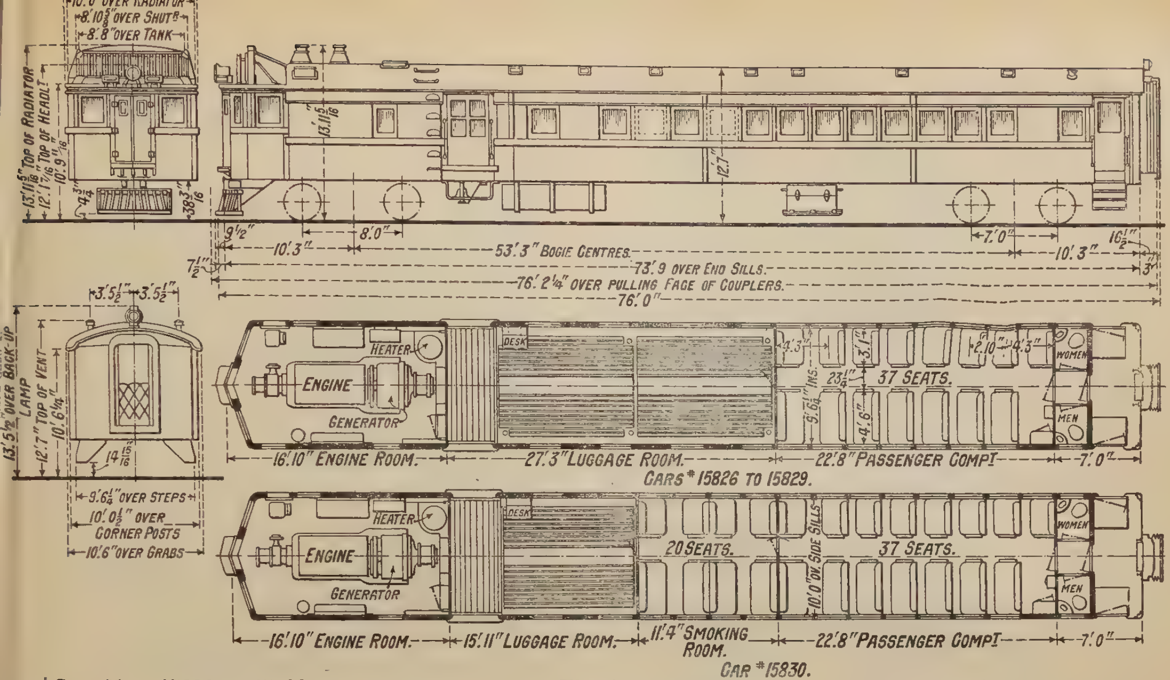
Date built	1924 (converted to gas electric 1926).
Builder	Canadian Car & Foundry Co.
Length :	
over bumpers	53 ft. 9 11/16 in.
» end sills	53 ft. 2 in.
» passenger compartment	23 ft. 8 1/2 in.
» smoking room	10 ft. 5 7/8 in.
» luggage room	none.
» engine room	13 8 1/8 inches.
Width :	
over side sills	8 ft. 9 in.
inside	8 ft. 3 in.
Height :	
inside	8 ft. 2 13/16 in.
from rail to roof	12 ft. 3 5/16 in.
Seating capacity :	
passenger compartment	34.
smoking room	16.
***Light weight of car :**	
front bogie	39700 lb.
rear	31700 lb.
total	71400 lb.
Style :	
of body	steel construction.
of vestibule	enclosed, trap door.
of doors : side	anti pinch hinge.
end	none.
engine room	sliding.
Windows :	
number	33.
size	24 × 31-inch glass.
style	ratchet stop.
Seats :	
size	3 ft. 2 in. overall.
upholstery	rattan.

*Weight of No. 15794 :

front bogie.	39700 lb.
rear »	31700 »
total	71400 »

Bogies :	
number	2.
type	4-wheel.
wheelbase : front	5 ft. 6 in.
rear	5 ft. 6 in.
total wheelbase	44 ft. 0 in.
Axles :	
size	3 3/4 inches.
material	steel.
Wheels	steel tyred.
diameter	33 inches.
Bearings	S. K. F. spherical self alig ing roller bearing No. 223 with adaptor sleeve.
Springs	double elliptic.
size	30-inch crs.
Engine :	
builder	Winton Engine Co, Clevelan
type	Model No. 124.
size	6-inch bore × 7-inch strok 120 B. H. P.
speed	1000 revolutions per minut
Generator :	
builder	General Electric 90 kw.
type	D.T. 510 A. Exciter T.E. 510
voltage	250 volts, 60-volt exciter.
Batteries	16 Exide L. X. R. 17.
capacity	120 Amp.—hrs., 32 volts.
Motors	4-General Electric 261, 25 H. each.
Lighting system	from battery 32 volts.
Brake equipment	Westinghouse, type A.M.M
Air compressor	Westinghouse, type D.H. 1
Headlight	Golden glow, type E.F. 1
Whistle	Westinghouse.
Bell	Daytona pneumatic.
Couplers	M. C. B. 9 1/4-inch. hea 5 × 5-inch. shank, 6 1/2-inch. end, bottom operated..
Sanders	Ohio Brass.
Heating	Peter Smith.
Lavatory	No. 22 Rex dry hopper.

Miscellaneous : engine generator set and control supplied by Electromotive Co, Cleveland, Ohio.



Cars Nos. 15826 to 15830. Fig. 3. Oil electric car.

Date built	1926-27.
Builder	Canadian National Railways.
Length:	
over platforms	76 ft. 0 in.
» end sills	73 ft. 9 in.
» main compartment	22 ft. 8 in.
» smoker	11 ft. 4 in.
» luggage compartment	No. 15 827 and 8 — 27 ft. 3 in. No. 15 827 and 9 — 27 ft. 3 in. No. 15 830 — 15 ft. 11 in.
Engine room	16 ft. 10 in.
Width:	
over side sills	10 ft. 0 in.
inside	9 ft. 6 1/4 in.
Height:	
inside	8 ft. 0 in.
from rail to roof	12 ft. 7 in.
Seating capacity:	
main compartment	37.
smoker	20.
luggage	nil.
Style:	
of body	steel construction.
of vestibule	steel.
of doors: side	swing.
end	swing.
luggage	sliding.
Windows:	
number	see diagram.
style	single raise sash.
Seats:	
size	4 ft. 6 in. in × 3 ft. 1 in.
upholstery	main compartment, mohair. smoking compartment, mohair.
Bogies:	
number	2.
type	4-wheel Commonwealth.
wheelbase: front	8 ft. 0 in.
rear	7 ft. 0 in.
total wheelbase	60 ft. 9 in.
Axles:	
size: motor bogie	5 1/2 × 10 inches.
» trailer	5 × 9 inches.
material	carbon steel.
Wheels	rolled steel.
diameter	36 inches.
Bearings:	
front bogie	5 1/2 × 10-inch. journals, S.K.F. boxes and bearings.
rear bogie	5 × 9-inch. journals, S.K.F. boxes and bearings.
Springs	elliptic motor bogie. helical motor bogie. elliptic trailer bogie. helical trailer bogie.
Engine:	
builder	Wm. Beardmore & Co Ltd.
type	6-cylinder 4-stroke cycle.
weight (engine and flywheel)	6 900 lb.
cylinders	8 1/4-inch. diameter, 12-inch. stroke, 300 B. H. P.
speed	750 revolutions per minute.
Generator:	
builder	Canadian Westinghouse Co.
type	198 K. W.
voltage	300 volts D. C.
Batteries	64 volts M. V. A. 17 Ironclad Exide.
Motors	2-569 C. 4 600 volts, 215 H. P. railway motors on front bogie.
Lighting system	32-volt storage batteries.
Brake equipment	Westinghouse: front bogie A.S.F. suburban type simplex clasp brake; rear bogie Canadian National Railways single type brake.
Air compressor	type D. H.-20.
Headlight	12-inch. Golden glow.
Classification lamps	Canadian National S. T. D.
Marker lamps	Canadian National S. T. D.
Whistle	2-Strombos horns.
Bell	locomotive type.
Couplers	Van Dorn 5 × 5-inch. shank, class « G ». 8 × 8-inch. spring.
Sanders	Hanlon.
Heating	Peter Smith hot water heater. Type O. C. 2 A.
Lavatory	Duner hoppers (2) wash basins (2).
Ventilation	exhaust type ventilators in roof.

Weight:
car No. 15826—141 400 lb. No. 15827—141 000 lb. No. 15828—141 000 lb.
No. 15829— — No. 15830—141 200 lb.

Miscellaneous: Modine radiators, Miniere window cleaners on front windows.

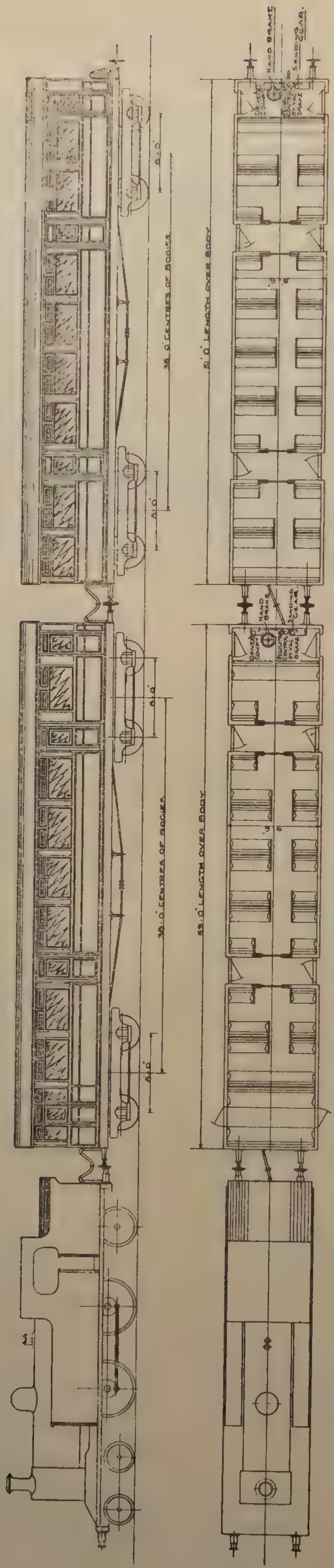


Fig. 4. — Diagram of reversible suburban train, controlled by vacuum brake, Great Northern Railway, Ireland.

articulated joint placed immediately above the rear driving axle. The passenger end of the coach is carried on a bogie of light but rigid construction. Details of the construction of the Sentinel engine and boiler are given in diagrams — figs. 5, 6, 7 and 8. The short time these vehicles have been in service is hardly sufficient to enable a decision to be given in regard to future extension, but valuable data is being obtained as to the usefulness and capacity of this type of vehicle for passenger work on branch lines, and on sections of the line carrying little traffic.

The London and North Eastern Railway report that :

On their system 44 Sentinel Cammell steam rail coaches have been introduced since 1925, 11 Clayton steam rail coaches since 1927 and a petrol rail coach in 1923. Of the 44 Sentinel Cammell vehicles, 24 are chain driven and 20 gear driven. Details of these vehicles are given in the diagrams — figs. 5 to 11 & 12 to 14.

A petrol-electric rail coach was introduced in 1911, but this is to be withdrawn and replaced by a steam rail coach.

No decision has been reached in regard to the extension of the use of the steam rail coach to meet future requirements.

The Southern Railway (Gt. Britain) report that :

On their system there are many instances where the traffic on branch lines is comparatively small, but is of a general nature and the motive power employed on the branch lines is required to work passenger, goods, timber, cattle, milk and other traffics thus the economical employment of a specially constructed vehi-

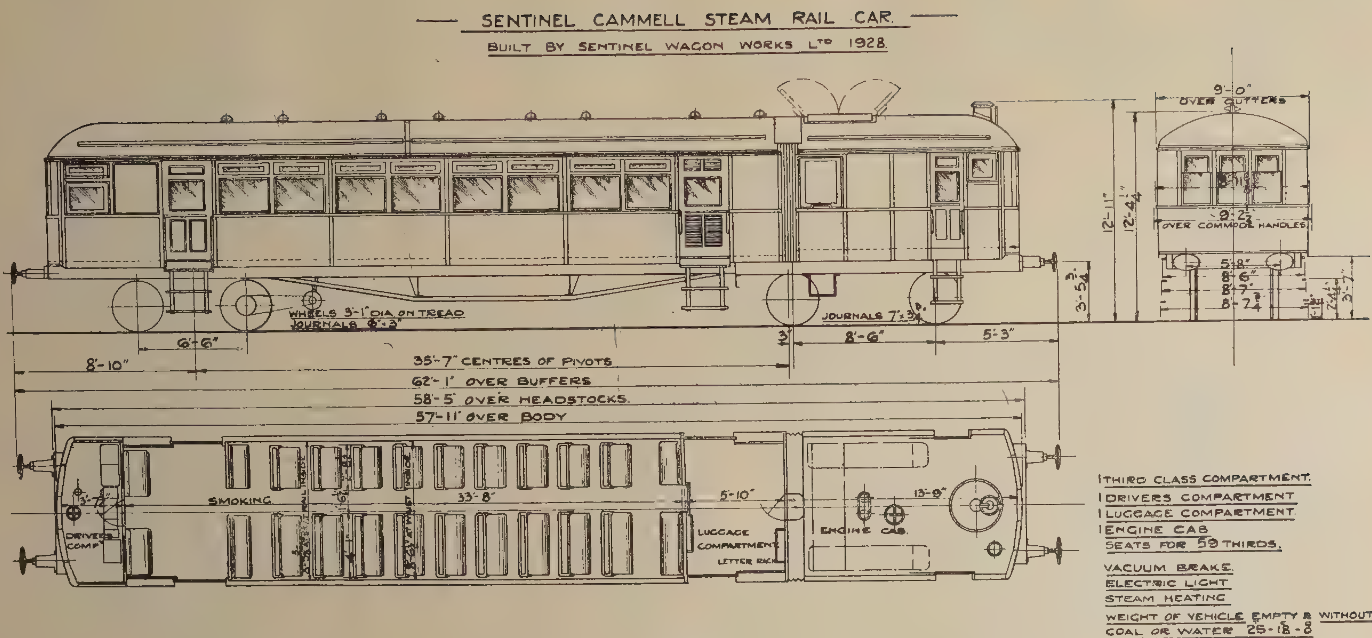

SENTINEL CAMMELL STEAM RAIL CAR.
BUILT BY SENTINEL WAGON WORKS LTD 1928.
9'-0" OVER GUTTERS
9'-2½" OVER COMMODE HANDLES
12'-11"
12'-4¼"
WHEELS 3'-1" DIA ON TREAD
JOURNALS 7"x 3¾"
6'-6"
8'-10"
8'-6"
5'-3"
35'-7" CENTRES OF PIVOTS
62'-1" OVER BUFFERS
58'-5' OVER HEADSTOCKS.
57'-11' OVER BODY
SMOKING
33'-8"
5'-10"
13'-9"
LUGGAGE COMPARTMENT
LETTER RACK
ENGINE CAB.
DRIVERS COMPT
1 THIRD CLASS COMPARTMENT.
1 DRIVERS COMPARTMENT
1 LUGGAGE COMPARTMENT.
1 ENGINE CAB
SEATS FOR 59 THIRDS.
VACUUM BRAKE.
ELECTRIC LIGHT
STEAM HEATING
WEIGHT OF VEHICLE EMPTY & WITHOUT COAL OR WATER 25-18-8

Fig. 5.

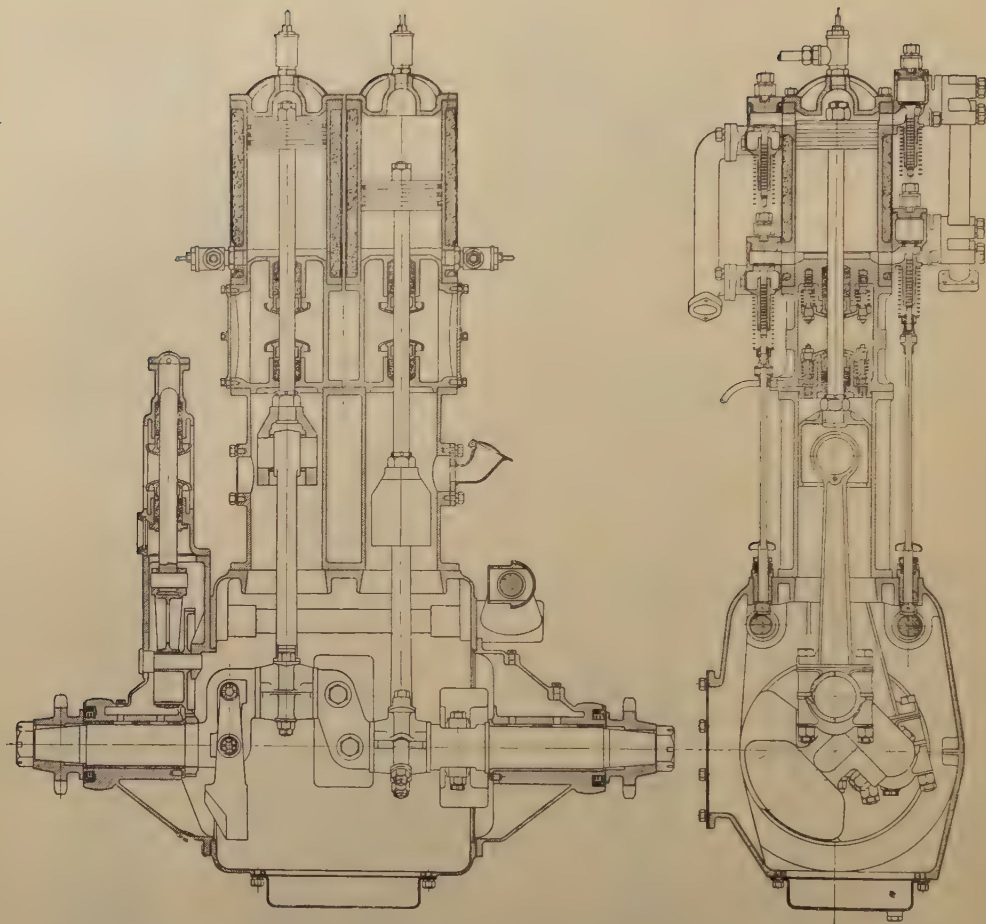


Fig. 6. — Cross section of engine, Sentinel Cammell steam rail car — chain driven.

cle such as a steam rail coach is precluded.

The Great Western Railway (Gt. Britain) report that :

In 1903 steam rail motor cars (fig. 15) were introduced to meet the demands of the passenger traffic on the minor lines. By 1907, 80 of these cars were in service, but this number has gradually decreased to 39. Generally speaking, the rail motor cars have been superseded in consequence of their lack of power and capacity to cope with extra traffic which may arise in various circumstances. The maximum loads up severe gradients are comparatively light and allow very little margin for extra vehicles to be attached. The method of working known as *auto trains* has superseded the rail motor cars except on branches and sections of the

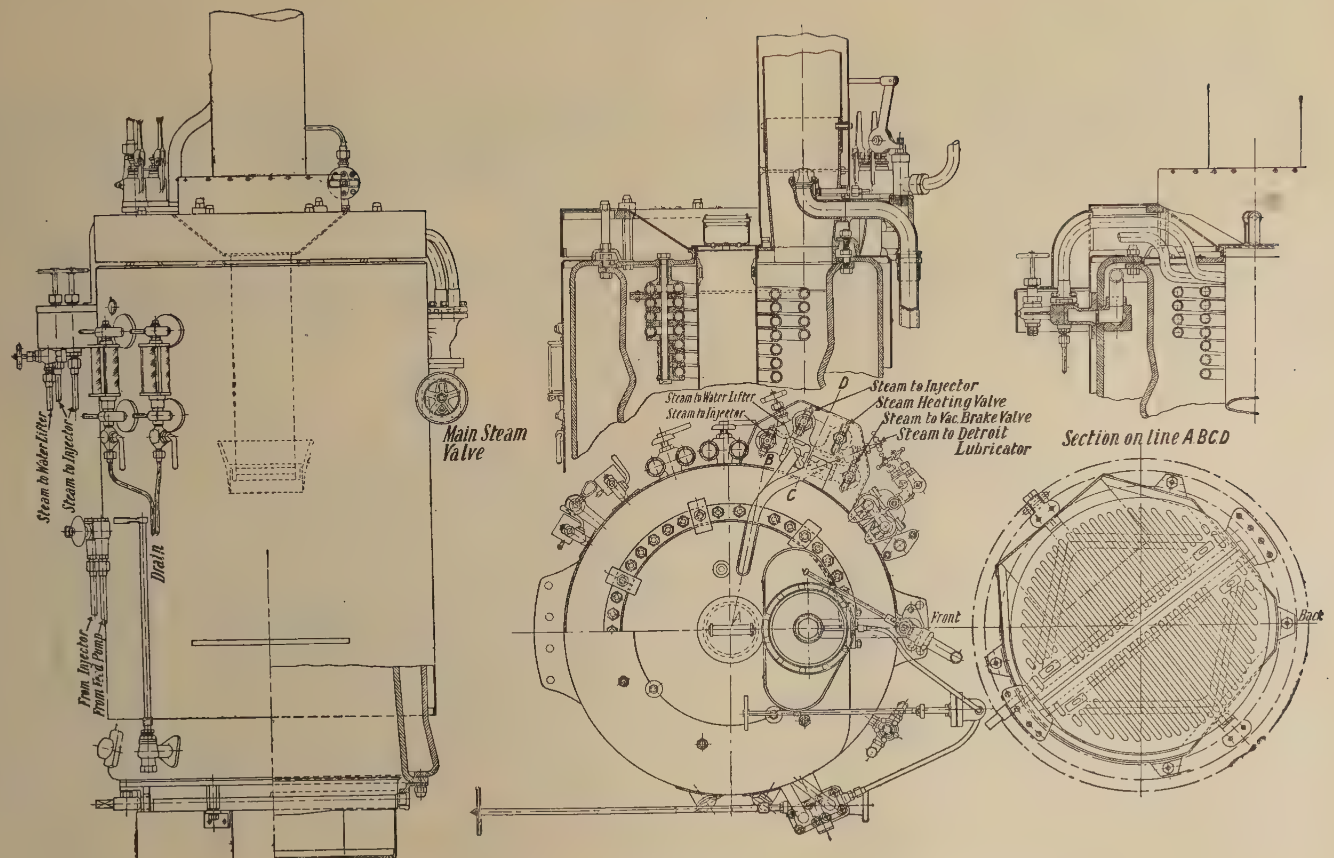


Fig. 7. — Standard 100 H.P. boiler and fittings, Sentinel Cammell steam rail car.

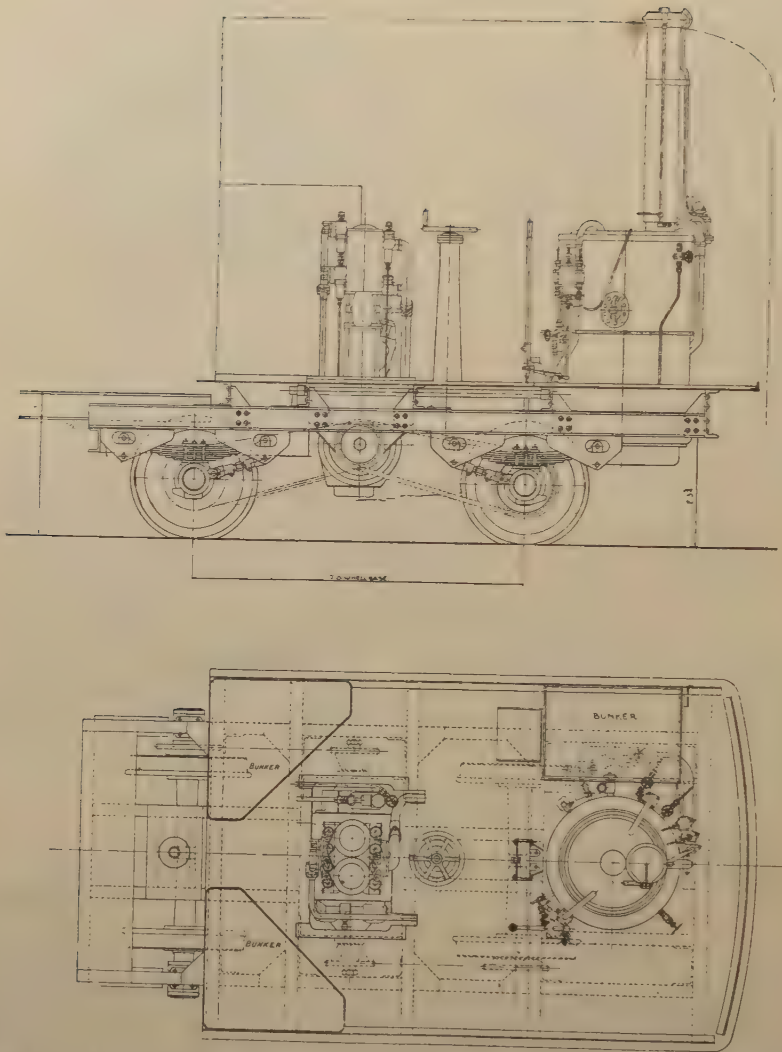


Fig. 8. — Arrangement of power unit, Sentinel Cammell steam rail car — chain driven.

line where the passenger traffic is fairly light. With this method a small tank steam locomotive is utilised and coaches are attached to it in front or behind, and in some cases at both ends, in such a way that the locomotive can be driven from either end of the train thus obviating the necessity of the locomotive running round its train at the terminal points.

It is of interest to note that the number of rail motor car services is now 15 as against 33 in 1907, while the number of auto train services is now 75 as against 14 in 1907.

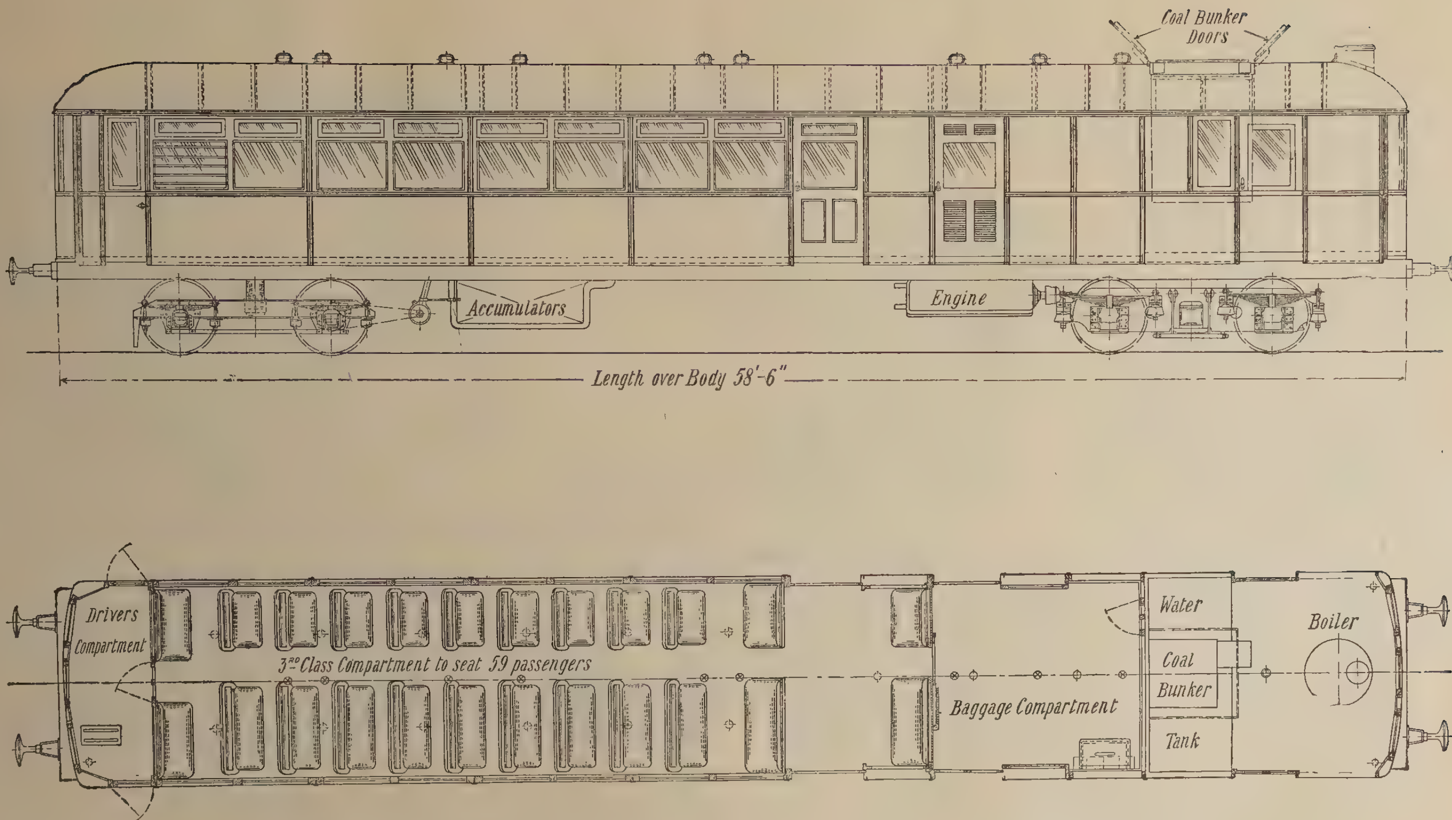


Fig. 9. — Standard gear driven Sentinel Cammell steam rail car, London & North Eastern Railway.

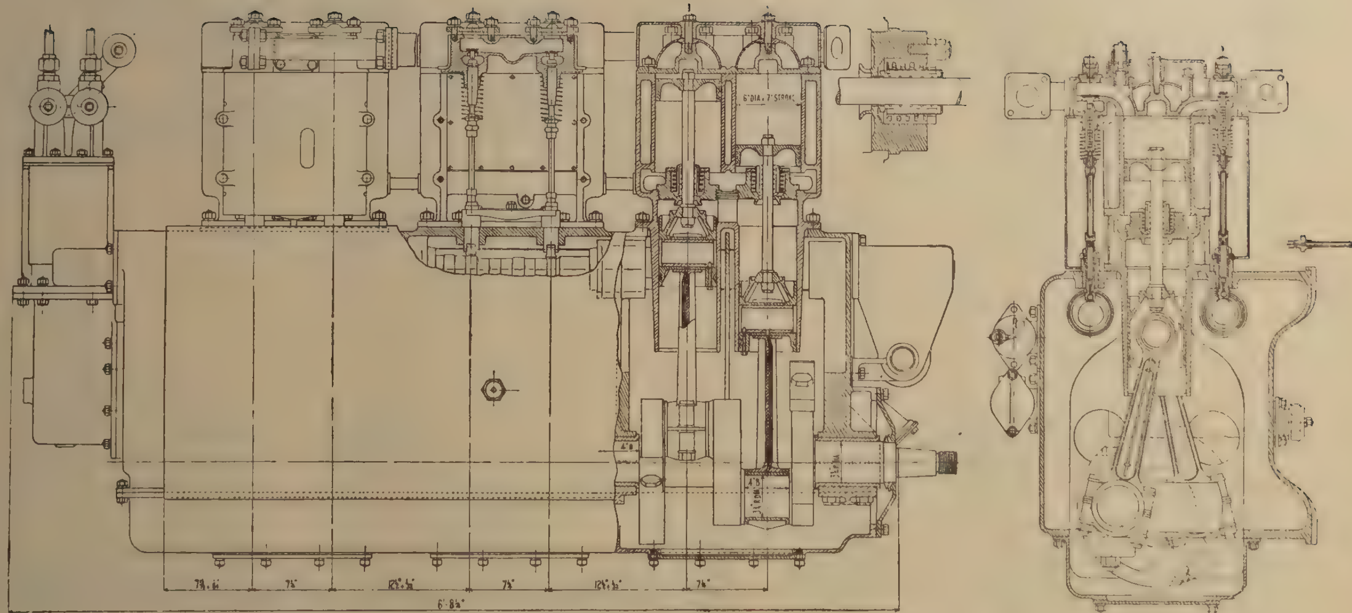


Fig. 10. — Six-cylinder single acting engine for Sentinel Cammell steam rail car — gear driven.

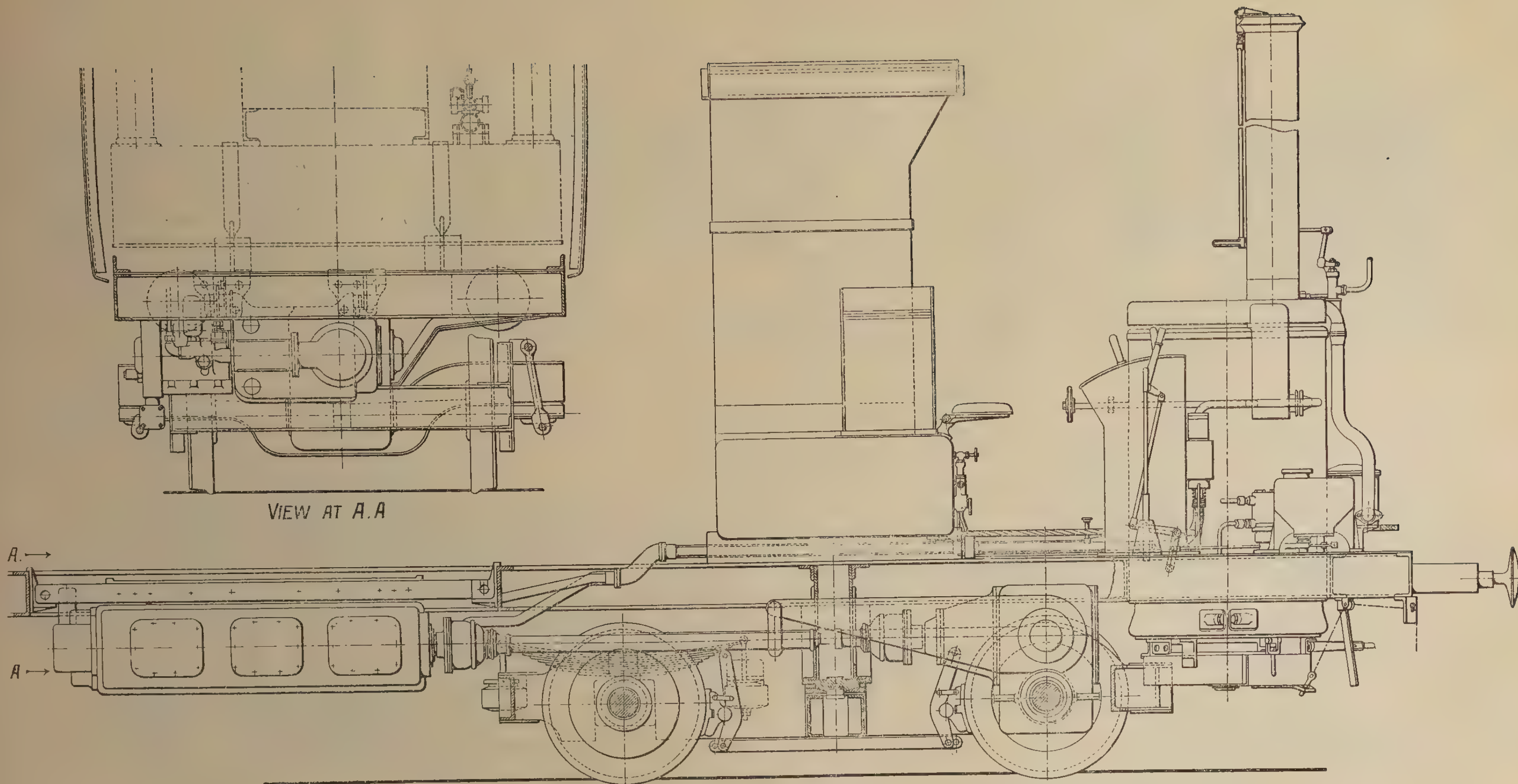


Fig. 11. — Arrangement of power unit, Sentinel Cammell steam rail car — gear driven.

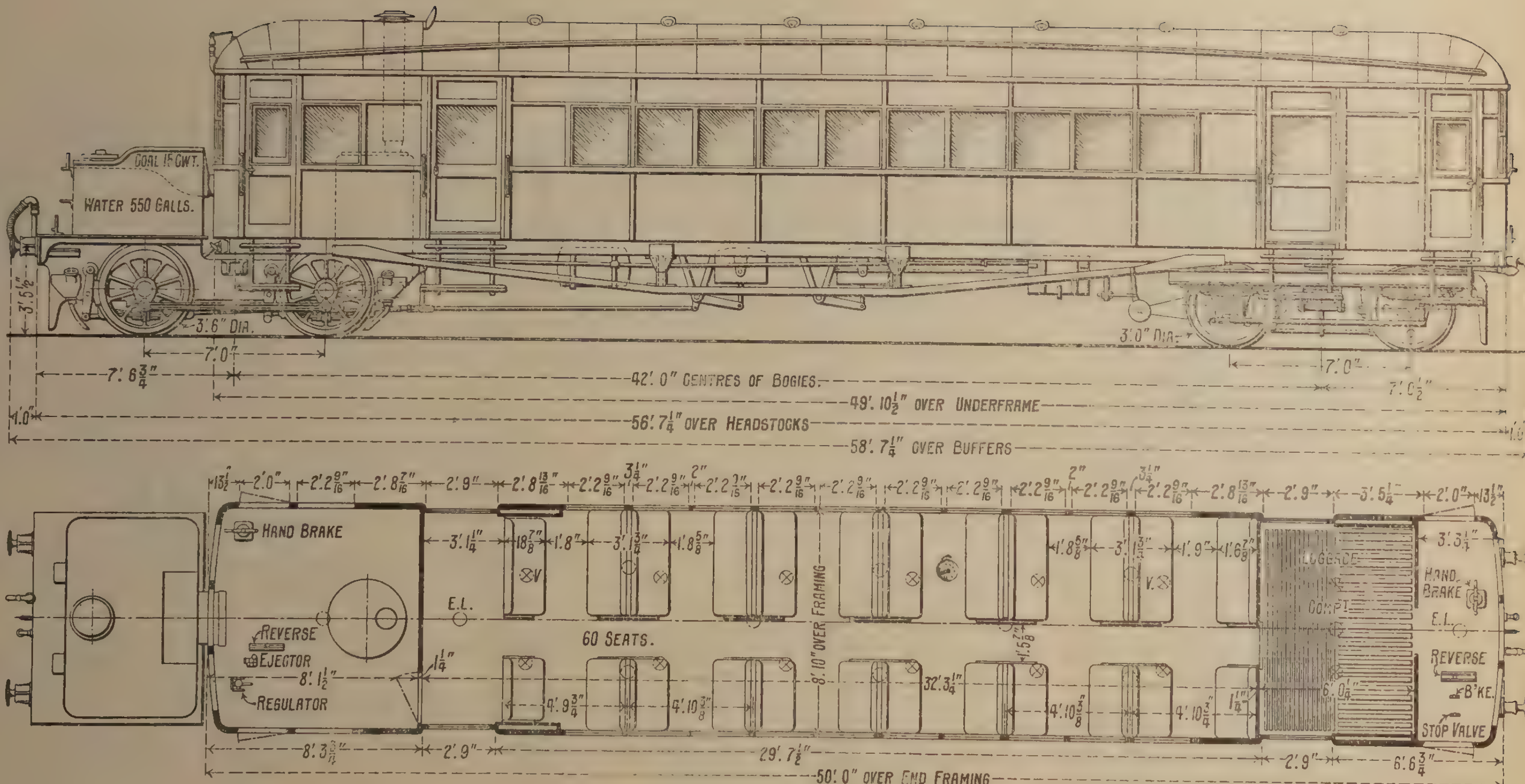


Fig. 12. — Clayton steam rail car.

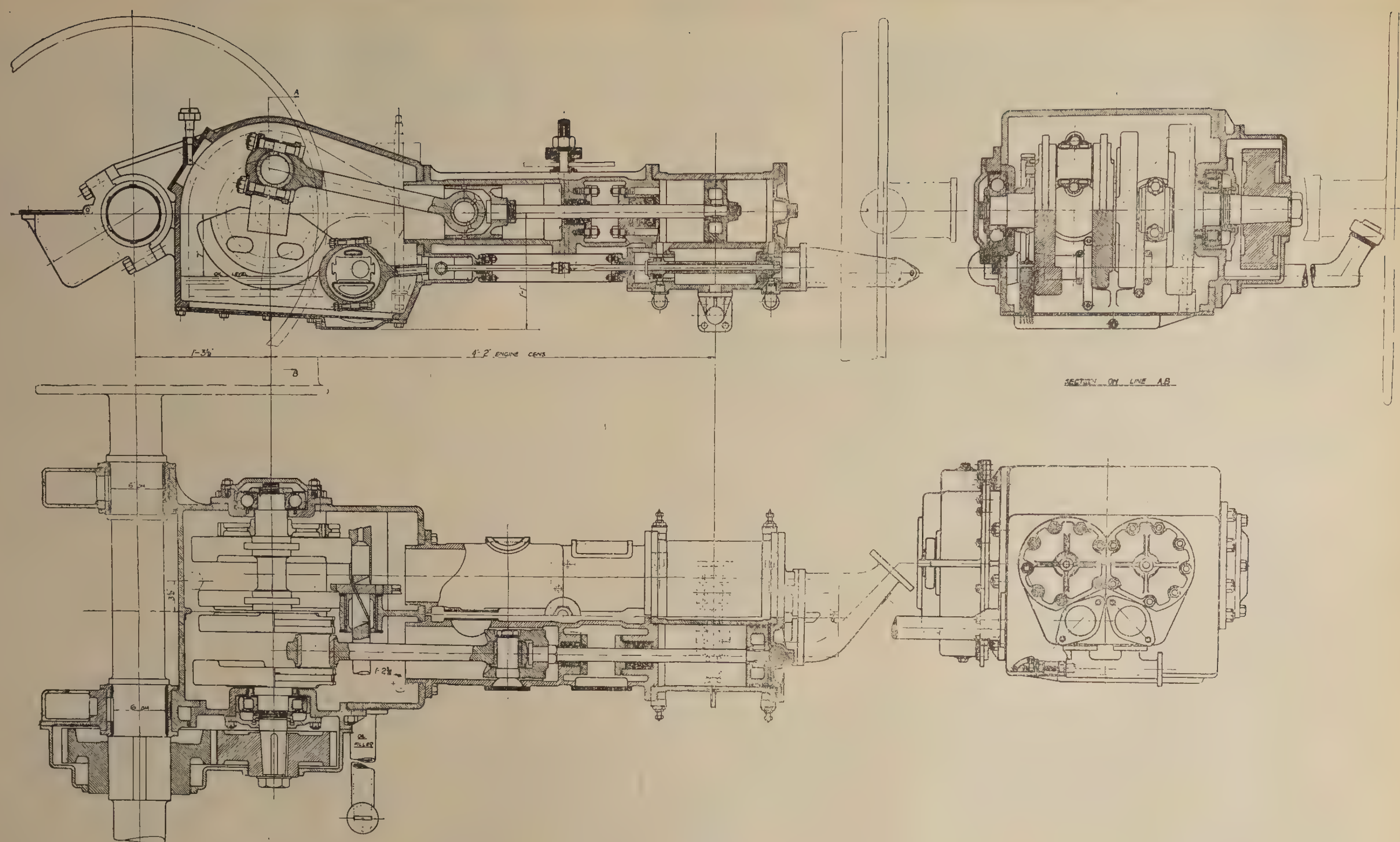


Fig. 13. — Arrangement of engine for Clayton steam rail car.

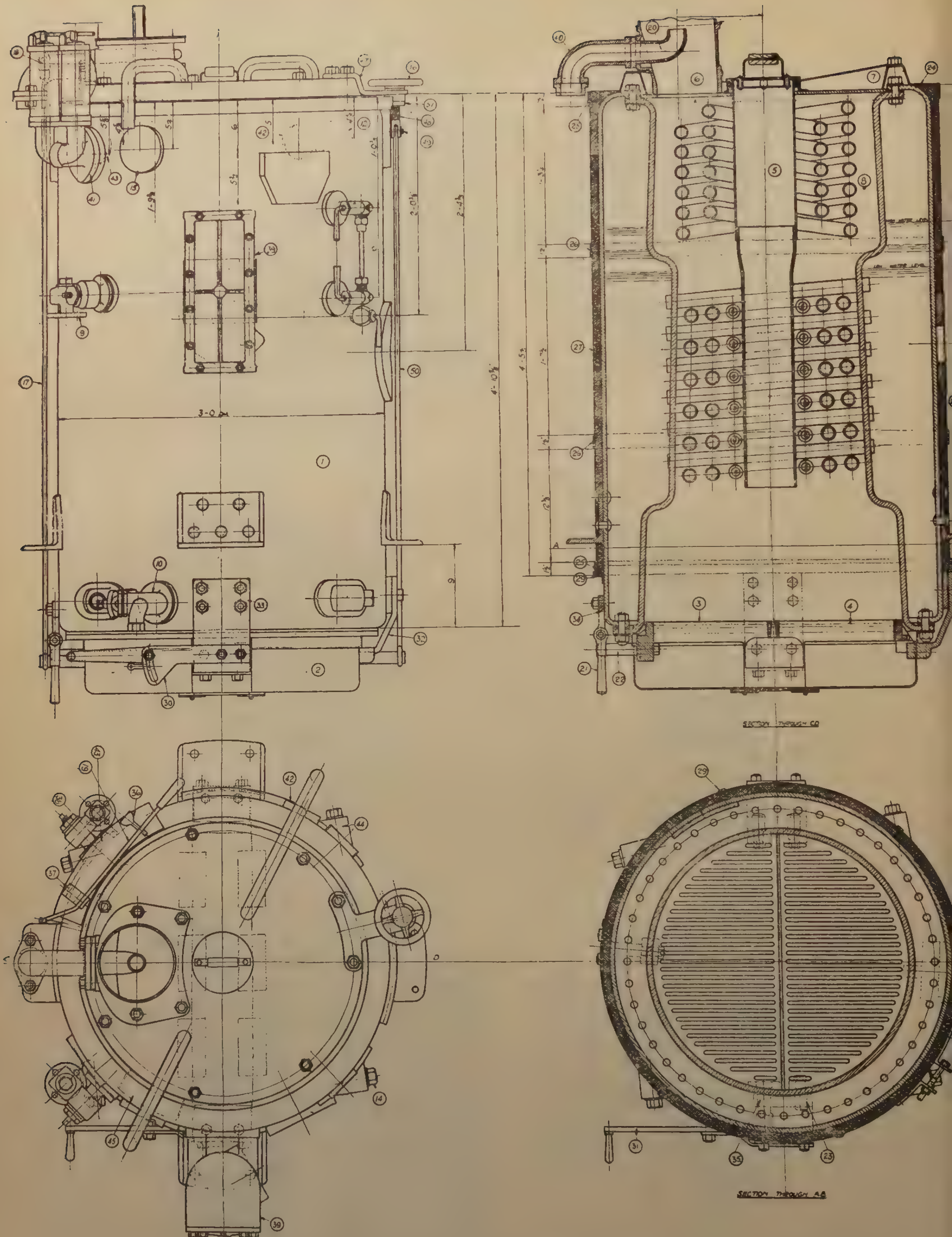


Fig. 14. — Arrangement of water tube boiler for Clayton rail car, London & North Eastern Railway.

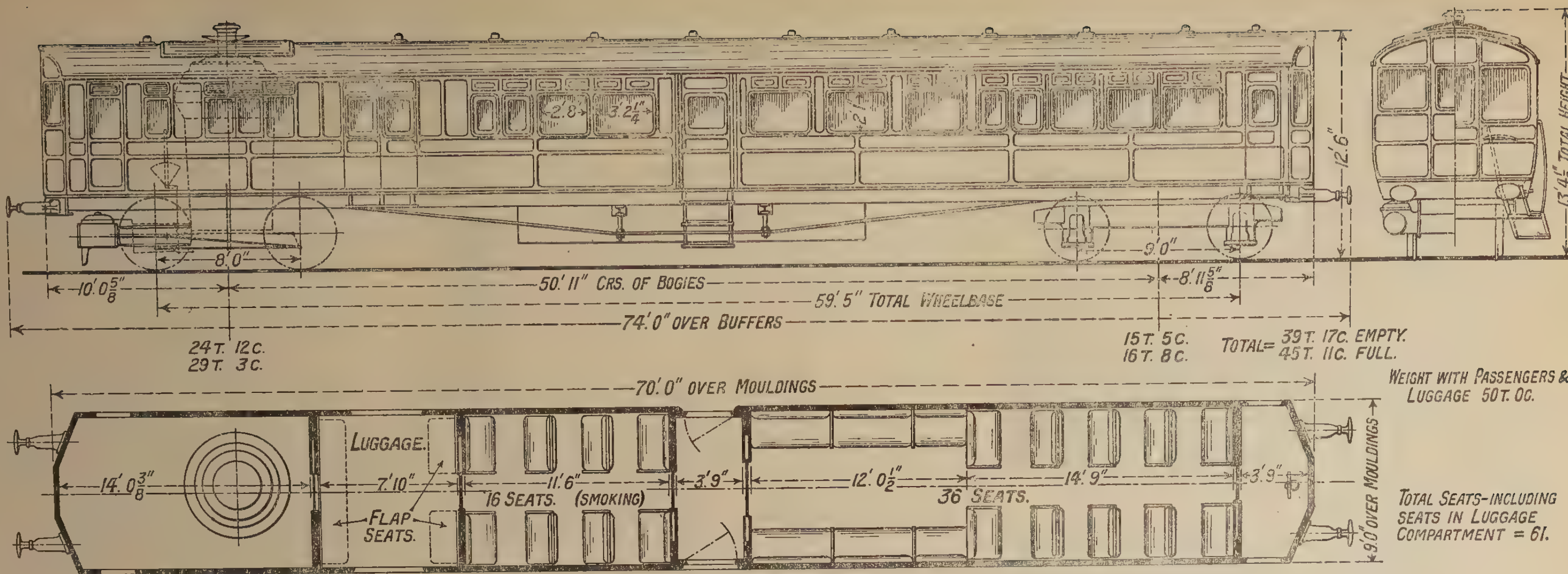


Fig. 15. — Steam rail motor car, Great Western Railway (Great Britain).

Cylinders:	
Diameter	12 inches.
Stroke	16 inches.
Boiler:	
Height	9 ft. 6 in.
Diameter	4 ft. 6 in.—
	6 ft. 1/8 in.
Firebox:	
Height	3 ft. 5 7/8 in.
Diameter	3 ft. 10 in.
Tubes:	
Number	419.
Diameter	1 1/4 inches.
Length	4 ft. 5 1/2 in.
Area of firegrate	11.54 square feet.

Heating surface:	
Tubes	611.32 square feet.
Firebox	46.46 square feet.
Total	657.78 square feet.
Wheels:	
Motor	4 ft. 0 in.
Bogie	3 ft. 7 1/2 in.
Water tank capacity	450 gallons.
Coal bunker capacity	30 cwts.
Working pressure	160 lb.
Tractive effort:	
At 90 %	6 910 lb.
At 85 %	6 525 lb.
At 80 %	6 145 lb.

The Great Western Railway's experience is that for branch services and sections of the line which demand a regular and constant passenger service, a self contained unit which can be driven from either end is required, particularly if the service is frequent. It is not possible to cope with the goods traffic economically by this method and other means must be provided to deal with this traffic. On a branch where the passenger and goods traffic are of equal proportions, a mixed train meets the requirements, and a light steam locomotive can usually haul this train both efficiently and economically with the advantage that it can perform any shunting necessary at intermediate or terminal stations. As a rule, several branches can be worked from a parent locomotive depot, and when this is so the number of light steam locomotives can be reduced as the number of spare locomotives necessary for maintenance purposes can be kept to a minimum. It is also advantageous from several points of view if these light locomotives form part of the standard stock as with locomotives not of the standard type, special arrangements have to be made to keep them in service or replace them.

QUESTION 1. — *Methods of economic traction employed for passenger trains on little frequented lines and for little used trains on more important lines.*

RAILWAY.	Method of traction.	Number of units in service.	Dates between which acquired.	Are similar methods employed for goods trains?
Canadian National	*a)* Storage battery cars.	6	1921-1923	No.
	b) Gasoline-electric cars.	4	1926-1928	
	c) Oil-electric cars.	14	1925-1927	
London Midland & Scottish	*a)* Light steam locomotives.	...	...	...
	b) Sentinel Cammell steam rail coaches.	13	1927	No.
London & North Eastern	*a)* Sentinel Cammell steam rail coaches:			No.
	chain driven.	24	1925-1928	
	gear driven.	20	1927-1928	
	b) Clayton steam rail coaches.	11	1927-1928	
Great Western (Great Britain)	*a)* Light steam locomotives.	...	...	...
	b) Steam motors.	39	1903-1907	No.

QUESTION 2. — The Canadian National Railways report that storage-battery cars will probably be replaced by oil-electric cars and to a lesser degree by gasoline-electric vehicles.

So far as the British Railways are concerned no decision has been reached as to the future use of special rail cars.

QUESTION 3. — *Steam motors.*

	RAILWAY.				
	London Midland & Scottish.	*London & North Eastern.*			*Great Western (Great Britain).*
A. Plan, wheel base, gauge, etc.	Sentinel Cammell (figs. 5 and 6).	Sentinel Cammell (chain) (figs. 5 and 6).	Sentinel Cammell (gear) (figs. 9 and 10).	Clayton (figs. 12 and 13.	Great Western rail motor (fig. 15).
B. 1. Type of boiler	Vertical, water tube (fig. 7).	Vertical, water tube (fig. 7).	Vertical, water tube (fig. 7).	Vertical, water tube (fig. 14).	Vertical.
Number of tubes	30	30	30	30	419 — 1 1/4 inch outside diameter 4 ft. 5 1/2 in. long.
Total heating surface, square feet.	67.2	71.5	73.0	70.0	657.8
System of superheating	Coil superheater.	Coil superheater.	Coil superheater.	Coil superheater.	None.
Maximum temperature of superheated steam.	600° F.	600° F.	650° F.	600° F.	...
Working pressure (lb. per sq. inch).	275	275	300	275	160
Nature of fuel	Coal.	Coal.	Coal.	Coal.	Coal.
System of grate	Ordinary.	Ordinary.	Ordinary.	Ordinary.	Ordinary.
Type of feeding apparatus	Steam driven feed pump and injector.	Steam driven feed pump and injector.	Steam driven feed pump and injector.	Steam driven feed pump and injector	2 live steam injectors.
Water level gauge	Two.	Two.	Two.	Two.	One.
Safety valves	Two.	Two.	Two.	Two.	Two — 3- inch diameter spring loaded.
B. 2. Mechanism. Single or double expansion.	Single.	Single.	Single.	Single.	Single.
Number of cylinders, their diameter and arrangement.	Two 6 3/4- inch diameter, 9- inch stroke, vertical.	Two 6 3/4- inch diameter, 9- inch stroke, vertical.	Six 6- inch diameter, 7- inch stroke, horizontal.	Two 7- inch diameter, 10- inch stroke, horizontal.	Two 12- inch diameter, 16- inch stroke, horizontal.
Type of distributors	Poppet valves.	Poppet valves.	Poppet valves.	Piston valves.	Balanced slide valves.
System of transmission of movement.	Chain.	Chain.	Gear.	Gear rod and crank.	Connecting rod and crank.
System of lubrication	Mechanical.	Mechanical.	Mechanical.	Mechanical.	Hydrostatic.
Arrangement of power unit	Fig. 8.	Fig. 8.	Fig. 11.	Fig. 13.	Fig. 15.

QUESTION 4. — *Daily average number of passenger trains, the number of corresponding train miles and the average frequency of those trains.*

LINE.	Daily average number of trains.				Daily average mileage.				Length of line, miles.	Average frequency.
	Ordinary.	Steam car.	Petrol car.	Total.	Ordinary.	Steam car.	Petrol car.	Total.		
Canadian National.										
On little frequented lines	...	...	41 (1)	41	..	...	3 311	3 311	3 862	
On more important lines	...	...	14	14	...	...	1 677	1 677	1 957	
Total. . .	...	...	55	55	...	...	4 988	4 988	5 819	
London Midland & Scottish.										Trains per hour.
On little frequented lines	...	62	...	62	...	138	...	138	7	4
On more important lines	...	121	...	121	...	1 029	...	1 029	159	7
Total. . .	...	183	...	183	...	1 167	...	1 167	166	7
London & North Eastern.										Average intervals.
On little frequented lines	661	424	28	1 113	5 159	2 775	83	8 017	370	89 minutes.
On more important lines	1 033	303	30	1 366	7 482	1 603	194	9 279	243	74 —
Total. . .	1 694	727	58	2 479	12 641	4 378	277	17 296	613	83 —
Great Western (Great Britain).										Trains per hour.
On little frequented lines	573	446	...	1 019	4 756	1 286	...	6 042	470	2.6
On more important lines	537	84	...	621	5 961	651	...	6 612	373	2.1
Total. . .	1 110	530	...	1 630	10 717	1 937	...	12 654	843	2.3

(1) Gas-electric and oil-electric.

QUESTION 5. — *Average daily number of passenger trains hauled by motors mentioned in question 1, corresponding train miles and average frequency of the trains, also minimum seating capacity necessary on minor lines.*

RAILWAY.	Type of car.	Average trains daily.	Average train-miles daily.	Average frequency.	Minimum seating capacity for minor lines.
Canadian National.	Gas-electric.	18	871	...	50
	Oil-electric.	37	2 496	..	...
	Storage-battery.	29	755	...	...
London Midland & Scottish. . .	Steam rail car.	183	1 167	Varies.	...
London and North Eastern. . .	Steam rail car.	727	4 378	83 minutes.	...
	Petrol car.	58	277		
Great Western (Great Britain) .	Steam rail motor.	530	1 937	Varies.	54

QUESTION 6. — *Daily average number of passenger trains which could be hauled by motors.*

No decision appears to have been reached which would enable reliable information on this point to be given at present.

QUESTION 7. — *Most difficult services performed by motors and information relating to those services*

RAILWAY.	Type of motor.	Most difficult journey.	Particulars of journey. Length		Duration.		Speed (miles per hour).			Composition of train.	Is punctuality sufficiently good ?	Can lost time be made up?
			Miles.	Chains.	Hours.	Minutes.	Average.	Maximum.	On incline.			
Canadian National. . . .	Gas-electric.	Brockville to Belville (Ont.)	95	0	4.	5	23.3	35.0	17.0	Car and. baggage car.	Yes.	Yes.
	Oil-electric.	Sherbrooke (Que.) to Quebec.	127	0	4.	20	29.3	50.0	25.0	Car and trailer.	Yes.	Yes.
	Storage-battery.	Campbellton to Bathurst (N. B.)	63	0	3.	0	20.0	30.0	15.0	Car and trailer.	Yes.	Yes.
London Midland & Scottish.	Steam.	Airdrie and Newhouse Bch.	3	62		12	19.0	...	...	Rail car. only.	Yes.	No.
London & North Easte n.	Ditto.	Harrogate to Knaresborough.	3	68		9F. 11R.	27.0	28.5	28.5	Rail car. only.	—	—
Great Western (Great Britain).	Ditto.	Exeter to Heathfield (Fig. 16).	17	3	1.	2	20.0	25.8	20.0	Car only.	Yes.	No.

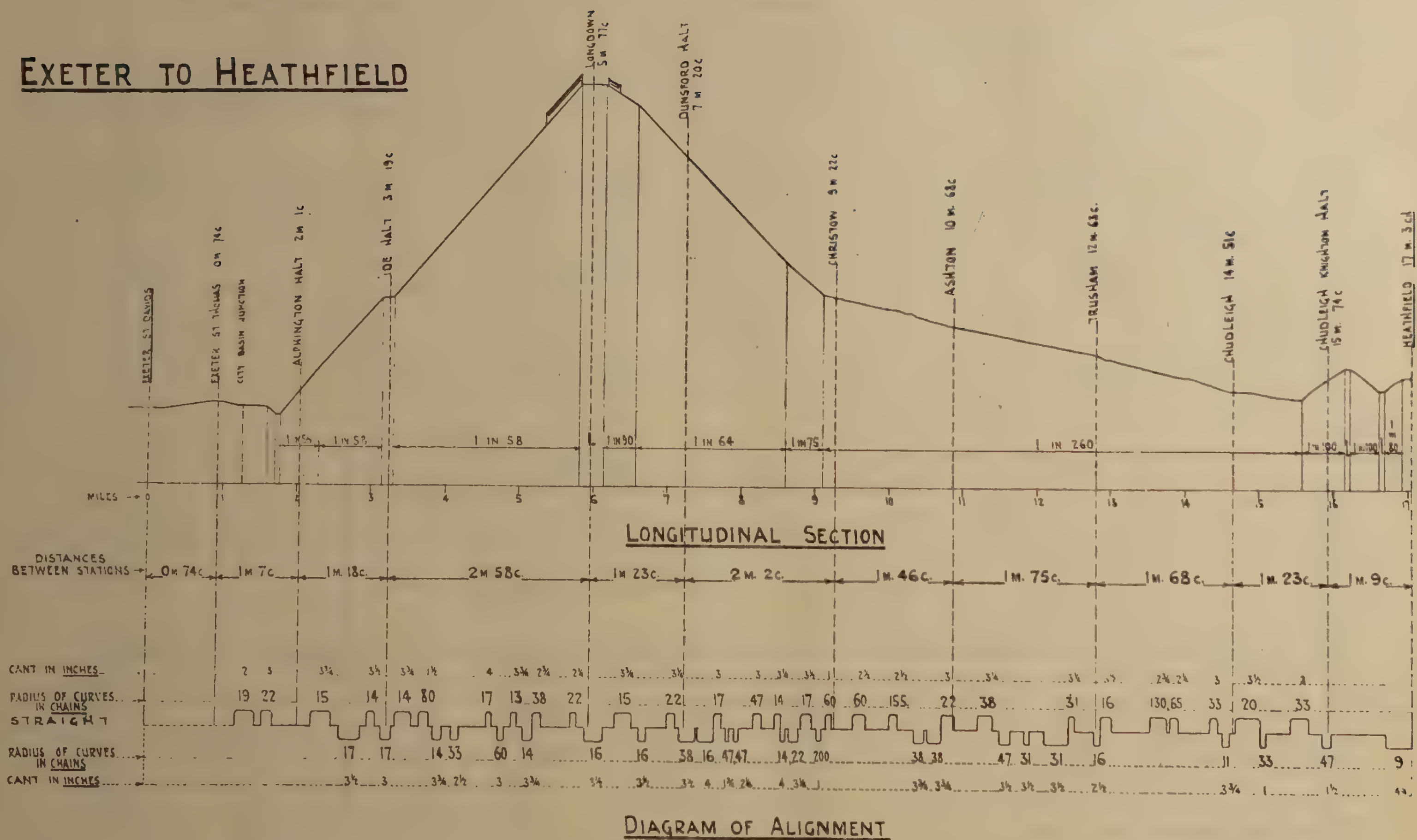


Fig. 16.

No true transition curves provided but slight easement curves exist in most cases.

QUESTION 8. — *Average daily number of units employed and number out of use by reason of repair, etc.*

RAILWAY.	Number of cars		Explanation for cars out of use.
	In use.	Out of use.	
London Midland & Scottish . . .	10	3	Repairs and service requirements.
London & North Eastern :			
Steam	42	13	Ditto.
Petrol	1	Nil.	
Petrol-electric	1	Nil.	
Great Western (Great Britain) .	30	9	Repairs, general and running, boilerwashing, etc.

QUESTION 9. — *Contemplated extension of the use of economical motors and motives which prompt same :*

Canadian National. — Extension of oil-electric cars contemplated and to a lesser degree gasoline-electric. A number of storage-battery cars will be converted to gas-electric eventually. Cars are too light for any other type of power unit.

London Midland & Scottish Railway. — No decision.

London & North Eastern Railway. — It is not possible to give a definite statement as the use of light units is still in the experimental stage.

Great Western Railway (Great Britain). — The use of steam rail motors is not likely to be extended in view of their limited capacity.

QUESTION 10. — *Information as to driving.*

	Canadian National.	London Midland & Scottish.	London & North Eastern.	Great Western (Great Britain).
Steam motors.				
Is it undertaken by one man or two? . .	...	Two: driver and fireman.	Two: driver and fireman.	Two: driver and fireman.
Is the number of men subordinate to certain conditions?	...	Fireman remains at boiler end. Driver works from whichever end is leading.	Fireman remains at boiler end. Driver works from whichever end is leading.	Fireman remains at boiler end. Driver works from whichever end is leading.
In what capacity are additional staff, if any, employed?	...	None.	Alarm signal provided, no guard or conductor necessary.	None.
Petrol and electric cars.				
Is driving undertaken by one man or two?	One.	...	One.	...
Is the number of men subordinate to certain conditions?	Depends on baggage, etc. carried.	...	Guard works with car.	...
In what capacity are additional staff, if any, employed?	Express employees or brakemen.	...	No.	...

QUESTION 11. — *Trains on which the entire control is confined to one man etc.*

	Canadian National.	London Midland & Scottish.	London & North Eastern.	Great Western (Great Britain).
Have you trains upon which the entire control is confined to one man?	No.	No.	No.	No.
Indicate method of issue and collection of tickets.	...	Issued and collected at stations.	...	Issued and collected at stations except at halts when conductor is responsible.

QUESTION 12. — *As to conditions of service.*

	Canadian National.	London Midland & Scottish.	London & North Eastern.	Great Western (Great Britain).
Are conditions of service on minor lines the same as on the main lines?	Yes.	Yes.	Yes.	Yes.
In each case over how many hours can the daily payment be spread?	...	Standard 8-hour day.	Standard 8-hour day.	Standard 8-hour day.
What unoccupied time may be deducted from payment time?	...	None.	None.	None.

QUESTION.	REPLIES.			
	Canadian National.	London Midland & Scottish.	London & North Eastern.	Great Western (Great Britain).
Number of coaches.				
Weight.				
Formation of coaches and engine.	The rail motor cars are self contained vehicles.			
Number of classes and seats				
Is there intercommunication between the coaches and between the locomotive and adjacent coach?	Figs. 1, 2 and 3.	See diagrams: Fig. 5.	Figs. 5 and 9.	Fig. 15.
Are trailer cars attached to rail motors?	Yes.	...	Yes.	Yes.
How many?	Maximum two.	...	Maximum one.	Maximum one.
Weight.	70 000 lb.	...	15 tons.	30 tons.
Number of seats	...	...	20	68
What influence does such a composition have on speed?	Varies according to gradients, curves etc.			
Have you any mixed trains?	No.	No.	No.	No.
QUESTION 14.				
Situation of driver's lobby etc.	See figs. 1, 2 and 3.	See fig. 5.	See figs. 5 and 9.	See fig. 15.
QUESTION 15.				
As regards rail motors, length of body etc.	See figs. 1, 2 and 3.	See fig. 5.	See figs. 5 and 9.	See fig. 15.
QUESTION 16.				
If there are two lobbies or two men employed in driving, where do these men take their posts?	See figs. 1, 2 and 3.	See fig. 5.	See figs. 5 and 9.	See fig. 15.
If only one driver where is he posted?	Always leading end.	Always leading end.	Always leading end.	Always leading end.
Is speed identical in both directions?	Yes.	Yes.	Yes.	Yes.

QUESTION 17. — *Information as to versatility of motor.*

QUESTION.	Canadian National.	London. Midland & Scottish.	London & North Eastern.	Great Western (Great Britain).
In case of a rush of passengers can load of train be increased?	See replies to question No. 13.			
Within what limits? What effect as regards speed?	See replies to question No. 13.			
Do you have recourse to ordinary locomotives?	Rail cars will handle normal traffic without difficulty. To meet exceptional circumstances (holidays, etc.) ordinary steam trains are substituted.			
Is a limit of capacity considered an inconvenience?	No.	Sometimes.	...	...

QUESTION 18. — *Are locomotives with internal combustion motors or explosion engines or rail motors stationed in locomotive sheds or in special sheds?*

Canadian National Railways. — Same roundhouse with steam locomotives.

London Midland & Scottish Railway. — Steam rail cars are stabled in locomotive sheds.

London & North Eastern Railway. — Steam rail coaches are kept apart from locomotives wherever practicable owing to their light construction and danger of damage by even slight collision. The boilers are more liable to freeze than those of ordinary locomotives.

The petrol rail car is kept in a special shed owing to inflammable nature of fuel.

Great Western Railway (Great Britain). — Steam rail motor cars are stabled in locomotive sheds.

QUESTION 19. — *Are they attended to by special mechanics or by those who deal with ordinary locomotives?*

Canadian National Railways. — All cars have a special maintainer detailed especially for that work.

London Midland & Scottish Railway. London, & North Eastern Railway. Great Western Railway. — By mechanics who deal with ordinay locomotives.

QUESTIONS 20, 21, 22, 23 and 24.

QUESTION.	REPLIES.			
	Canadian National	London Midland & Scottish.	London & North Eastern.	Great Western (Great Britain).
20. — Maximum distance that can be run on regular service.	...	...	Daily mileage of about 200 is the present normal working.	...
21. — Maximum speed on level stretch.	Approximately 60 miles per hour.	...	Approximately 40 miles per hour.	No restrictions except by booked times which allow of an average of 30 miles per hour deducting stops.
22. — What difficulties have been met with from point of view of maintenance.	New development involves education, etc.	...	No exceptional difficulties yet experienced.	None beyond ordinary wear and tear.
23. — Difficulties in connection with quality of water.		None.	Do.	None.
24. Public attitude towards light trains, rail motors, etc.		Diversity of opinion.	Generally favourable.	When rail motors and trailercars were first used 1st class passengers complained of absence of 1st class accommodation but since that time the use of private motor cars has increased to such an extent that 1st class travel on branches has practically ceased.

—	London Midland & Scottish.	London & North Eastern.	Great Western (Great Britain).
QUESTION 25.			
Average consumption of fuel including that for lighting and when stationary.	Coal : 15 lb. per en ine-mile.	Coal : 12 to 13 lb. per mile. *Petrol car :* 5 miles per gallon. *Petrol-electric :* 3 5 miles per gallon.	Coal : 25 lb. per engine-mile.
QUESTION 26.			
Average cost per train-mile (steam cars).			
Fuel	1.30 d.	1.13 d.	2 49 d.
Lubrication	0.14 d.	0.18 d.	0.07 d.
Lighting	0.33 d.	0.10 d.	...
Water	0.06 d.	0.11 d.	0.17 d.
Locomotive staff	4.98 d.	5.25 d.	7.29 d.
Cleaning and maintenance of mechanical portion of car.	1.76 d.	3.06 d.	5.29 d.
Cleaning and maintenance of coach portion if additional to ordinary coaches.	...	1.31 d.	..
Price per unit :			
Fuel	15 sh. 11 d.	15 sh. 8 d.	19 sh. per ton.
Lubricating	2 sh. 9 d.	2 sh. 9 d.	1 sh. 0.9 d. per gallon.
Water	1 sh.	10 1/2 d.	1 sh. per 1 000 gallons.
Average cost per train mile (petrol car).			
Fuel	..	2.31 d.	...
Lubricating	...	0.33 d.	...
Lighting	...	0.10 d.	...
Water	...	...	...
Locomotive staff	...	2.70 d.	...
Guard	...	1.39 d.	...
Cleaning and maintenance :			
Engine.	...	1.81 d.	...
Coach	...	1.09 d.	...
Price per unit :			
Petrol	...	1 sh. per gallon.	...
Special oil	...	2 sh. 9 d. —	...
Ordinary.	...	1 sh. —	...

QUESTION 27. — *Average cost per train-mile where an ordinary locomotive is used which is economically best appropriated to the trains in question.*

—	London Midland & Scottish.	Great Western (Great Britain).
Fuel	5.39 d.	2.95 d.
Lubricants	0.19 d.	0.08 d.
Lighting	0.33 d.	...
Water	0.29 d.	1 sh. per 1 000 gallons.
Locomotive staff.	4.97 d.	7.29 d.
Cleaning and maintenance. .	4.59 d.	3.96 d.

QUESTION 28. — *Average purchase price of motors and credit to be expected.*

Purchase price.	£ 3 892	Approx. £ 4 000
Credit to be expected	£ 195	£ 175

QUESTION B.

Use of special tractors for shunting in smaller yards and for certain work in large yards.

The Canadian National, Great Northern of Ireland and *South African Railways* report that there are no special tractors employed for shunting purposes in the smaller yards; all the shunting work is performed by steam locomotives.

The London Midland & Scottish Railway report that :

Their practices are as follow :

1. *Goods depots.* — At the larger goods depots shunting power (after the herthing of trains in the road adjacent to the goods premises by locomotive engines under the control of the Chief General Superintendent) is performed by capstans, the power driving the machinery of which is taken either from hydraulic or electric machinery; the capstan units being located at convenient points for carrying out the work of berthing rafts of wagons in the warehouse roads or conveying individual wagons from a road laterally by traverser to the road upon which it is desired to discharge such vehicles.

In the case of capstans operated by hydraulic power, hempen ropes having at the end at which connection is made with the vehicles, a short chain of suitable

capacity about 6 feet long and fitted with a steel capstan hook at the end, the hook is attached to the « V » of the axle guard of a wagon and usually a movement of approximately 15 to 20 wagons may be carried out at one operation.

In the case of electrically driven machinery, the rope is attached permanently to the capstan bollard by means of a slot cut in the bollard, through which the rope is fastened on the inside of the drum : the cable in this case being of steel wire of suitable dimensions coiled into rope, with similar means of attachment to that prevailing in the case of the hempen type of rope. The foregoing arrangements apply mainly at depots of sufficient density of business as to warrant the expenditure of capital involved in installing plant of this capacity.

In the case of smaller stations — and in some cases at depots at which such power driven machinery is provided — shunt horses suitably harnessed with cross tree and shunting hook chain trailing from the hind quarters of the animals, are utilised for movement of individual wagons when power driven machinery is not available; the attachment in this case being to the horse eye fixed on the solebar of the railway wagon.

2. *Coal depots.* — So far as coal depots are concerned, the major portion of shunt is conducted by :

a) Large yards : Chiefly shunting engine power but at certain depots in London, power capstan installation.

b) Medium sized yards : Chiefly shunting engine power.

c) Small yards : Shunting engine and shunt horse power.

On similar lines to those operating in respect of goods yards.

Staff qualifications. — Prior to the men being permitted to take charge of capstan operations a period of training usually extending over three or four weeks, is given with a view to ensuring that the work is carried out under conditions which will ensure safety of the staff and operation.

It is the practice of this Company to consider any improved methods for dealing with this aspect of working, i. e., shunting, as they come under notice and in certain instances petrol driven tractors have been instituted where it is found that the employment of such machines can be more economically adopted than carrying out the operation by means of capstan installation or shunting by locomotive power.

The *London & North Eastern Railway* report that :

The special methods of traction on their system are :

Horses.
Sentinel steam locomotives.
Simplex petrol locomotives.
« Fordson » road tractor.
« Towmotor » road tractor.
M[c] Cormick Deering tractor.
Capstans with cables.

and the following information has been supplied :

Method of traction.	Capacity.	Speed (miles per hour).	Staff.	When introduced.	Particulars of cost.
Horses.	One or two loaded wagons or three or four empty wagons.	3	One driver and chain lad where necessary.	Since inception of railways.	Hourly cost = 2 sh.
Road tractors.	5 to 10 loaded wagons or 8 to 15 empty wagons.	From 1 to 10.	Motor driver and chain lad where necessary.	Within recent years.	*Consumption.* 4 miles per gallon of petrol when employed on heavy work.
Sentinel shunting locomotive. (fig. 17.)	10 loaded wagons or 15 empty wagons.	From 4 to 10.	Driver only on power unit.	Within recent years.	*Consumption.* 12 to 17 lb. of coal per mile (shunting mileage) calculated at 5 miles per shunting hour.

No special difficulties have been experienced with the introduction of the special types of traction, and the results so far are quite satisfactory. The use of power units, is, however, in the experimental stage and sufficient experience has not yet been gained to give detailed figures of maintenance and cost of repairs.

The tendency is to replace horses by power units where this would be advantageous and economical.

The Southern Railway report that :

Horses are utilised for shuttle working of empty and loaded wagons from main yards into sheds for loading up purposes and they are capable of dealing with 2 loaded or 4 empty wagons.

Fordson motor tractors were introduced about four years ago and are used for shunting of loaded and empty wagons from siding in main shunting yard into other sidings, contiguous to delivery yards for unloading purposes, also shunting loaded and empty wagons from riverside wharves, granary and delivery yard after being individually collected by capstans working from loading positions, to the main yard for despatch.

The machine is a standard Fordson tractor fitted with rubber tyred road wheels. The rear driving wheels are loaded with cast iron turnings to increase the weight and so obtain improved tyre adhesion to the road. The body of the tractor is surrounded by a substantial steel girder frame to support the buffer plates.

The capacity of the tractor is :

4 loaded wagons ascending gradient.

10 loaded wagons descending gradient.

8 to 10 empty wagons ascending gradient.

12 to 20 empty wagons descending gradient.

At the Nine Elms depot where 3 Fordson tractors are in use, 9 pairs of horses were previously employed to perform the same work.

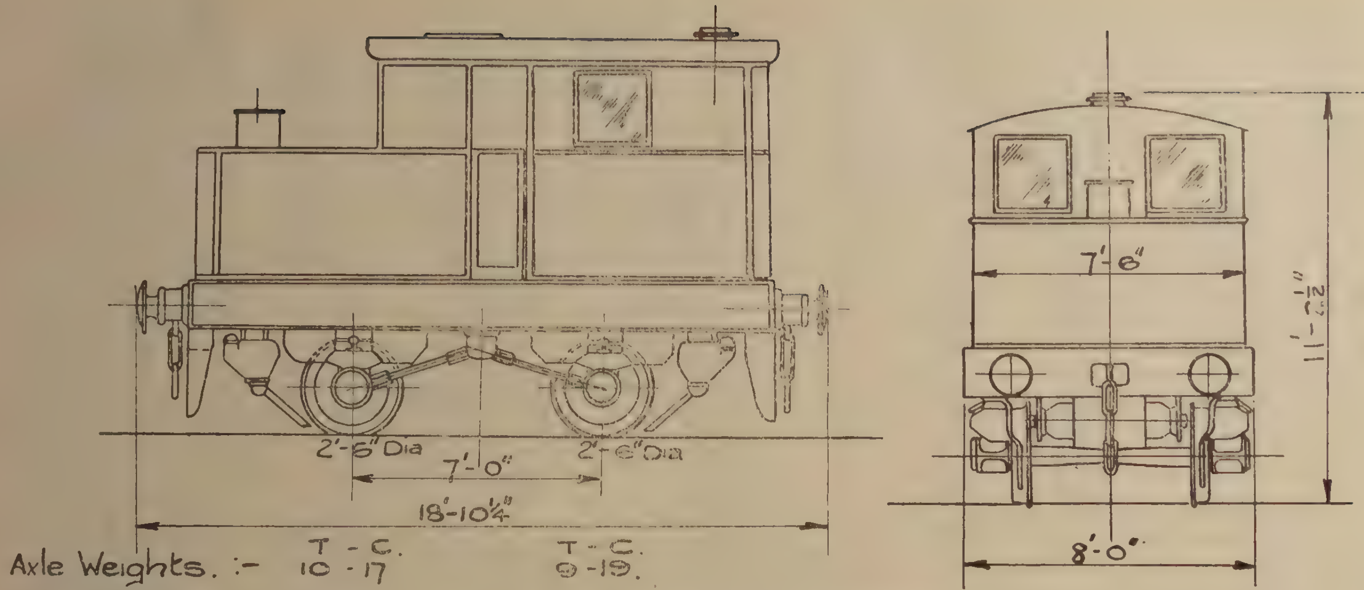


Fig. 17. — Type Y-3 Sentinel 0-4-0 shunting locomotive (Section L. N. E.).

Characteristics, leading dimensions and ratios.

Built: The Sentinel Waggon Works Ltd. 1927.

Capacity of bunkers	16 cwts.
Capacity of tank	300 gallons.
Empty weights:	
Engine	18 tons 13 cwts.
Boiler	2 tons, complete with 5 cwts of water.
Maximum weight in working order, total	20 tons 16 cwts.
Grate area	5.10 square feet.

Axles — journals:

Diameter	5 1/2 inches.
Length	10 inches.
Springs — laminated:	3 ft. 0 in. centres.

11 plates 4 1/2 inches wide, 7/16 inch thick.

Cylinders:

Number	2.
Diameter	6 3/4 inches.
Stroke	9 inches.
Horsepower	260 H. P. at 750 r. p. m.

Height	4 ft. 10 1/2 in.
Internal diameter at top	1 ft. 11 1/2 in.
Internal diameter at bottom	2 ft. 6 1/2 in.
Thickness of steel plate	11/16 inch.
Boiler: Water tube:	
External diameter at top	3 ft. 1 in.
External diameter at bottom	3 ft. 3 1/2 in.
Total height	4 ft. 10 13/32 in.
Thickness of steel plate	19/32 inch.
Tubes:	
Material	Steel.
Number	30.
Outside diameter	2 inches.
Thickness	10. S. G. W.
Superheater	Coil.
Heating surface:	
Firebox	35 square feet.
Tubes (2-inch diam.)	36.5 square feet.
Total	71.5 square feet.
Working pressure, lb. per square inch.	275.
Boiler horsepower.	120.

Type of valve	Poppet.	
Cut-off in full gear	80 %.	
Tractive effort at 85 % B. P.:		
Low gear	9 300 lb.	
High gear	3 400 lb.	
Adhesive weight ÷ tractive effort:		
Low gear	5.0.	
High gear	13.7.	
Total adhesive weight	45 600 lb.	
Gear ratio:		
Low gear	18-71 gears, 19-19 sprocket.	low 11.5.
High gear.	36-53 gears, 19-19 sprocket.	high 30 5.
Revolutions per minute of engine:		
500 at maximum speed.		
Braking horse power of engine:		
100 at 500 revolutions per minute.		
Low gear tractive capacity:		
260 tons at speed of 10 miles per hour.		
Brake: Combine steam and automatic vacuum.		

Tractors are available practically at all times at short notice except when severe climatic conditions prevail during Winter months. In wet or frosty weather grit is thrown over the ground where they traverse, to prevent slipping and give grip particularly over cobbled areas.

The staff employed are:

One tractor driver, weekly wage 60 sh., who is responsible for the manipulation of the tractor.

One see-over man, weekly wage 52 sh., who is responsible for giving the signal to tractor driver when wagons are ready for movement.

One rope runner, weekly wage 52 sh., who attends on the tractor driver for purposes of moving or affixing rope or chain utilised between tractor and wagons for pulling purposes.

The introduction of the tractors has, undoubtedly, accelerated the shunting work.

No special installation has been found necessary as the tractors are berthed in the goods shed van dock.

The cost of purchase of the tractor is £ 260, and the maintenance per tractor per annum is £ 170 for repairs and £ 25 for renewals and depreciation.

The Great Western Railway report that:

The general practice is to employ specially designed steam locomotives for shunting purposes at all yards where any considerable traffic is dealt with. At small yards, such as in the case of country stations, the shunting is ordinarily performed by the train engines.

In the case of six yards, however, where physical difficulties, viz., sharp curves, prevent the employment of ordinary shunting engines, five petrol driven locomotives and one steam locomotive of a special type are employed.

The following particulars give constructional details of the petrol engines (Simplex) :

Type : Standard 8-ton, 4-cylinder, 40 B.H.P.

Wheelbase : 5 ft. 6 in.

Length over buffers : 13 ft. 4 in.

Length over headstocks : 10 ft. 4 in.

Height overall : 9 ft. 7 in.

Height of platform : 4 feet.

Capacity : Engines running at 1 000 revolutions per minute and developing 40 H. P.

Petrol consumed : About 9 pints per hour.

For particulars of the Sentinel steam locomotive see figure 17.

The Simplex engine will haul 11 loaded or 15 empty wagons on the level. The Sentinel locomotive is capable of hauling 84 tons up a gradient of 1 in 51, part of which gradient is on a curve of 160 feet radius.

At some of the above named yards horses were formerly employed for shunting and it has been found that the shunting work has been expedited by using these special engines. In addition, considerable working economies have been effected, *e. g.*, in the case of one yard where with horse shunting it was necessary to empty two horse drivers and two slipper boys, the use of the Simplex engine has resulted in the work being performed with one engine driver and one shunter. Economies have also been effected with the introduction of the Sentinel engine in view of the fact that it can be operated by one man.

Horse shunting. — As regards shunting by horse power, a total of 91 horses is employed at places where the curves are too sharp or headroom insufficient to use an engine; also where, in view of the intermittent character of the work to be done, horse shunting is the most economical.

The following information is submitted with regard to the utility of horses and the cost of operation :

Average number of wagons dealt with at time per horse :

1 passenger coach, full or empty, or
1 loaded goods wagon, or
2 empty goods wagons.

Speed of movement :

3 to 4 miles per hour.

Hourly cost of horses :

Per horse per hour 5.15 d.
Per driver per hour 1 sh. 1 d.
Total : 1 sh. 6.15 d.

Salary of driver (wages, clothing and insurance) :

£2-12-1 d. per week.

Capstan shunting. — Capstan shunting is only employed where space is restricted and no other means of moving wagons can be employed. It is a method of shunting not generally favoured.

Haulage capacity of Simplex petrol engine.

Speed, miles per hour.	Tractive effort, (lb.)	Tons hauled : On level.	Up 1 in 100.	Up 1 in 60.	Up 1 in 20.
3	3 400	146	68 1/2	48 1/2	17
7.2	1 540	62	26	17	3 1/2

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REPORT No. 2

(Belgium, France, Holland, Italy, Portugal, Spain and their Colonies)

ON THE QUESTION OF THE METHODS FOLLOWED IN TRAINING OF STAFF, PROFESSIONAL, TECHNICAL AND ORDINARY WORKING GRADES (SUBJECT XVI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Mr. BARTH,

PRINCIPAL ENGINEER, HEADQUARTERS OF THE FRENCH EST RAILWAY.

The professional, technical or general education which a railway employee possesses, and which he can place at the disposal of the administration by which he is employed, is made up of the knowledge acquired by him before entering the railway service and of the knowledge acquired in that service. It has, therefore, appeared to us advisable to distinguish between these two kinds of knowledge and to examine, firstly, the methods adopted when recruiting staff to obtain a selection of the most suitable candidates and, secondly, the methods adopted for improving and perfecting the training of the staff thus selected. This distinction is brought out in the questionnaire (see Appendix I), which was addressed to 97 administrations (see Appendix II) and to which 32 of them have submitted replies.

I. — Selection of candidates.

All the administrations which have replied to our questionnaire appoint candidates directly from outside to most of the posts in their service. *The Belgian National Railway Company*, however, accepts outside candidates for its lower grade and certain middle grade occupations only; the other posts are reserved for the Company's employees.

For the lowest grade occupations, where no special knowledge is necessary, such as station workmen, labourers in the rolling stock or permanent way maintenance service, crossing keepers, etc., all that is required in general from candidates is that they should be able to read, write and count. On certain railways, moreover, such as the *Paris, Lyons & Mediterranean* and *Midi Railways* and the *Tunisian Railway Company*, even this degree of elementary education is not essential, and the examination which the candidates are required to undergo — where indeed there is any examination at all — is intended solely to ascertain the extent of their education.

Candidates for employment as tradesmen undergo a practical « test » bearing on their particular occupation.

On the *Great French Railways* (« *Grands Réseaux français* ») and on the *Algerian Lines* of the *Paris, Lyons & Mediterranean Company*, these « tests » are the subject of very strict regulations. For each particular occupation the work to be carried out in the tests is, in general, al-

(1) Translated from the French.

ways the same; the time normally required for its execution has been determined, and the materials and tools are supplied to the candidate.

If the test is completed in the time allotted, the candidate receives 13 marks; if the time taken is longer or shorter than the time alloted, the marks are calculated as follows :

Supposing N to represent the time allotted; then each quarter of an hour gained or lost on this time carries an increase or decrease in the 13 marks, equivalent to $\frac{3.5}{N}$.

The candidate further receives :

— marks between 0 and 20 for the speed with which the work is performed; these marks are given the coefficient 4 and are the most important;

— marks for the quality of the finished work, with the coefficient 3;

— marks for reading drawings, for the manner in which the work is set out and for care of tools. These three sets of marks have the coefficient 1.

If the final marks for the quality of the finished work are less than 13, the candidate has failed to pass the examination.

In order to be accepted as a workman in his particular trade, the candidate must have total marks of not less than 130; if he has less than 130 he can only be engaged as an « handyman or fitters labourer »; if he has less than 60 he can only be engaged as an ordinary labourer.

For appointment to the staff of the administrative offices, a certain level of general education is required; candidates must pass an examination or tests in writing and spelling, elementary arithmetic, the metric system and composition; for appointment to the Operating Department posts of certain railways, candidates must also answer questions in geography; further, candidates may, at their option, take tests in foreign languages and typewriting.

For appointment to the technical office staff, tests in algebra, geometry, mechanics and designing are added to those mentioned above.

Finally, for appointment to the higher posts, diplomas are required.

The *Great French Railways* have adopted very precise regulations in this connection : the diplomas which are taken into consideration by the railways have been classified, according to their value, in a certain number of groups, and each of them qualifies candidates for appointment without examination to given employments; a matriculation certificate for example, only qualifies under these conditions for posts as beginners; on the other hand, the diplomas of the Ecole Polytechnique, of the Ecole Centrale de Paris, etc., qualify for appointment to higher posts; a candidate appointed to the railway staff under these conditions must first pass through a series of stages in those branches of the service with the technicalities and working of which he must make himself familiar, and only then can he be given definite employment. Appendix III gives details of the practice followed by the various railways, showing the nature and duration of these stages.

We have also endeavoured to ascertain — although this somewhat exceeds the scope of our present inquiry — whether railway administrations, as regards occupations for which certain qualities, such as coolness, rapidity of decision, etc., are particularly essential, adopt methods of selection which enable them to discover the candidates who possess these qualities and to eliminate those who are without them. Most of the administrations con-

sulted have informed us that they do not adopt such methods, but merely take steps to ascertain that candidates are physically fit; they state that the simple nature of the occupations to which candidates are put at the outset does not necessitate the possession of any special qualities, and that the process of selection follows automatically in the ordinary course of work.

The *Société des Transports en Commun de la Région Parisienne*, on the other hand, has organised a whole series of selective tests for candidates for employment as drivers, conductors and specialist workmen. Appendix IV gives the details supplied to us in this connection. The methods therein described have, it appears, resulted in a reduction from 18 to 4 % in the proportion of driver candidates who have to be eliminated during the period of apprenticeship; as regards occupations, the results are not yet known.

II. — **Apprenticeship.**

We have indicated above the methods adopted by the railways for the selection of candidates; the majority of the railways, with a view to maintaining an efficient trained staff, adopted in addition the apprenticeship system. The system is particularly intended to supply the Chief Mechanical Engineer's Department with workmen and officials; certain railways, however, also train employees for the operating Department and workmen for permanent way service.

The *French Est Railway* train about 400 apprentices each year; the *Paris-Orleans*, the *Paris, Lyons & Mediterranean*, the *French State* and the *French Nord Railways* each train about 200.

The *Société des Transports en Commun de la Région Parisienne* train 3 000 yearly, but these are conductors and drivers, in whose cases the period of apprenticeship is much shorter.

On all the railways which adopt the apprenticeship system, it is the practice to give preference to children of employees or former employees of the railway. The children make application through their parents or guardian; they must be not less than 13 or 14 and not more than 16 or 17 years old; the Belgian railways accept them up to the age of 18.

To qualify for apprenticeship candidates must, as a rule, pass an examination similar to the elementary school leaving examination. On certain railways, however, as for example the *Belgian National Railway Company*, the *Portuguese Railway Company*, etc., there is no preliminary examination.

In the case of the *Société des Transports en Commun de la Région Parisienne*, the *Great French Railways* (with the exception of the *Midi*), the *Portuguese Railway Company*, the *Tunisian Railway Company*, and the *Algerian Railways of the Paris, Lyons & Mediterranean Company*, etc., the apprentices are indentured. Under the indentures the father, the mother or the guardian of the apprentice undertakes, in consideration of the remuneration which the latter receives, to agree to his engagement, at the end of his apprenticeship, on the permanent staff of the railway, if the railway so desires. The railway reserves to itself the right, on the one hand, to decide, after the expiration of a certain period, for what occupation the apprentice shall be trained (fitter, turner, etc.) and, on the other hand to modify the terms of remuneration should there be any modification in the terms applying to employees of the permanent staff. The indentures also provide for disciplinary measures in case of unsatisfactory service; these measures

may extend as far as cancellation of the apprenticeship. The indentures also provide for penalties payable by either party in case of breach of contract.

For the purpose of apprenticeship training, the apprentices are sometimes grouped among themselves and sometimes work in collaboration with the regular employees. The first method is that adopted, for example, by the *French Est Railway;* at each of the main repair shops and main engine depots, courses are arranged for the training of apprentices as fitters, joiners, etc.; apprenticeship training for the occupation of boilermaker, smith, turner, etc., is given at the engine sheds at Epernay.

In the case of the *Belgian National Railway Company*, on the other hand, the apprentices, during their period of training, participate in the ordinary duties of the regular employees. As the workshops are in the vicinity of trade schools, the apprentices are encouraged to attend these schools, where they can acquire all the theoretical and practical instruction they require.

The training given to apprentices varies greatly : on certain railways it consists entirely of manual work; on others, such as the *Belgian National Railway Company* and the *North of Spain Railway*, it is supplemented by theoretical instruction; finally, general instruction is given in addition by the *Great French Railways*, the *Tunisian Railway Company*, the *Société des Transports en Commun de la Région Parisienne*, the *Algerian Railways of the Paris, Lyons & Mediterranean Company* and the *Algerian State Railways*.

The training lasts for two years with the *Tunisian Railway Company*, the *Andalusian Railways and the Portuguese Railway Company;* it lasts for three years with the *Great French Railways;* it lasts for only one or two months for conductors and drivers with the *Société des Transports en Commun de la Région Parisienne*. The manual training is given by specialist workmen under the supervision and control of officials.

The training of apprentices is controlled by means of periodical examinations. The parents of apprentices are, in general, kept informed as to the marks obtained; these are written in a record book (« carnet d'apprentissage ») which must be signed periodically by the parents.

In general, a diploma is granted at the end of apprenticeship to apprentices who have given satisfaction.

Apprentices receive remuneration : their remuneration increases, in general, in proportion to their ability to render actual service. A certain number of railways, and in particular the *Great French Railways*, where the marks obtained are sufficiently good, grant bonuses on completion of apprenticeship in the form of savings bank books.

Certain railways enter into an agreement to give the apprentice employment on termination of apprenticeship, provided he has given satisfaction. Other railways make a practice of giving employment without, however, entering into any undertaking to do so.

Appendices V and VI give more detailed information regarding the apprenticeship organisation of, firstly, the *French Est Railway* and, secondly, the *Société des Transports en Commun de la Région Parisienne* (conductors and drivers).

III. — Supplementary apprenticeship courses.

On certain railways the normal apprenticeship courses are followed by supplementary courses for apprentices who are sufficiently well reported upon.

With the *French Paris-Orleans Railway* these courses are of two kinds : firstly, apprentices who possess a sufficiently advanced theorotical education are admitted to a Higher Apprenticeship Course, and, secondly, apprentices who, while not being eligible for this Higher Course, have nevertheless during their period of apprenticeship shown manual dexterity and a sufficient degree of intelligence, are allowed to take a fourth year of apprenticeship, during which the instructors do not merely ensure that the pupils carry out their work correctly, but endeavour to teach them the reasons underlying the work done.

The pupils for the Higher Course are selected from among the first year apprentices by means of an examination to which only those apprentices are admitted who have given satisfaction in the workshops; the examination does not, however, comprise a manual test; the only subjects are French, drawing, mathematics and science. Apprentices who succeed in passing the examination sign a special contract whereby they undertake to remain in the service of the railway for five years after completing their training; these five years may either follow their period of military service, or be partly before and partly after. They undertake further, in case this obligation is not fulfilled, to pay to the company the sum of 500 francs.

The courses last three years; the subjects taught are : 1st year, arithmetic, geometry, trigonometry, algebra, mechanics, drawing, technology; 2nd year, mechanics, geometry, physics, technology, political economy; 3rd year, mechanics, electricity steam engine, chemistry and French. The cost of text books, note books and working equipment is borne by the students. The instruction is given by employees of the company under the supervision of higher officials. Examinations are held twice a year, at Easter and at the end of the year; where students do not obtain sufficiently high marks in these examinations, they are not allowed to continue the course.

Toward the end of the third year the pupils spend six weeks in the offices in order to gain some acquaintance with administrative routine.

At the end of the three years' course of study, pupils who have satisfactorily passed the final examinations receive a diploma, setting out distinction achieved, if any. The award of these diplomas is entered in the apprentices' records as in the case of university diplomas.

Between the time of leaving the school and entering upon military service, pupils who have received diplomas with distinctions spend one year in workshops of that branch of the service to which they belong (engines-carriages-wagons); during this period they work in turn with all the different gangs of workmen in order to acquire sufficient experience to enable them to carry out any inspection or repair work themselves. During the second year they are attached to foremen for the purpose of familiarising themselves with the control and supervision of workmen and with the bookkeeping and statistical work performed by these foremen.

On their return from military service those former apprentices who hold diplomas complete the stages of training which they were unable to complete before leaving for military service; they are then required to pass through a series of occupations in which they can rapidly acquire the knowledge and experience necessary to fit them to hold the higher posts in workshops, repair shops and depots.

In the case of the *French Est Railway* the fourth year of apprenticeship takes place after the period of military service; this arrangement affords more opportunity during the years preceding military service of discovering which apprentices are best fitted, by reason of their intelligence, assiduity and good conduct, for appointment to post of responsibility; it also permits of giving the pupils, within a short space of time, the grade of assistant foreman or foreman : the prospect of early promotion is an excellent form of encouragement.

In order that apprentices may not, between the end of their third year and their departure for military service, forget the theoretical knowledge they have acquired, arrangements are made for revision, both orally and by correspondence, during this interval of time : this revision covers the whole of the subjects previously studied.

Only candidates who have shown great promise during their third year are allowed to continue for a fourth year.

The courses of training provided for former apprentices are also available for other employees and we shall give in Chapter IV some details of their organization and the subjects taught.

We have endeavoured to ascertain whether, apart from apprenticeship, certain railways adopt any special methods with a view to obtaining candidates possessing a sufficient standard of education and whether, in particular, they have entered into arrangements with certain schools for this purpose. We find that no railway has entered into any such arrangements : the Great French Railways, in particular, have indeed for several years been paying subsidies — in some cases of considerable amount — to large schools (Ecole Polytechnique, Ecole Centrale, etc.), but these subsidies have the appearance rather of generous donations than of subsidies for a particular purpose. We may, however, quote the case of the *Thiès-Niger Railway*, which makes a yearly grant of 50 000 francs to the Bamako Trade School, which school provides the railway with about 20 native employees each year; at Thiès there is further a trade school provided specially for the railway. *The Damascus-Hama Railway* details certain *higher* officials to give courses of instruction in certain trade schools, but does not undertake to show any special preference to candidates coming from these schools.

IV. —**Training of existing staff.**

Having examined the methods adopted by the various railways for securing staff of satisfactory quality, we will now examine the methods employed for completing the training of the staff already appointed.

The methods most generally adopted are the following : instruction given at the place of work by responsible employees (particularly the instruction given to engine crews by head drivers); the placing at the disposal of employees of service orders or instructions concerning their particular branch; the distribution (either free or against payment, according to the particular railway) of text books specially compiled for the use of the staff and containing theoretical and practical instruction on the various branches of work, on the apparatus and appliances in use, etc., periodical lectures given by experienced officials either during working hours (in which case attendance is compulsory) or outside working hours.

Certain railways, moreover, encourage employees who attend lectures or those who give them by granting special bonuses to those who obtain the best results.

The *Paris-Orleans Railway* have also instituted *evening courses* at their more important centres. These courses are available to all employees of the company and are intended to improve the general education of the staff, not to provide special instruction for any branch of the service. They are held twice a week and comprise an elementary division and an advanced division. The subjects taught are French, arithmetic (simplification of fractions, metric system, mixtures and alloys, proportions), elementary algebra, mechanics, technology, electricity, geometry (conic sections, intersections, projections, perspective).

The *Midi Railway* have organized a *professional training service* the object of which is to train beginners, to allot them to that branch of the service for which they are best fitted and to complete the training of employees already in the service.

Candidates for employment as general labourer, watchman, superviser, time-keeper, train attendant or messenger are required, before being allowed to enter upon such employment, to undergo a preparatory course lasting for ten days; this course is taken at the instruction centre of that section of the railway to which the candidate belongs.

Not later than the seventh day from the beginning of the course the instructor divides the candidates for employment as general labourers into three categories :

a) employees fitted for the traffic service;

b) employees fitted for duty as pointsmen or for directing shunting or maintenance work;

c) employees fitted only for manual occupations.

It is on the basis of this classification that the chief official of the department decides the final destination of each candidate.

After completing their preparatory stage, candidates for employment as watchman, superviser or time-keeper are detailed to assist an employee of their own grade for a sufficient length of time to enable them to become familiar with the details of the service.

Train attendants on trial are, after having completed their preparatory stage, placed for ten days under the supervision of a train controller detailed for this purpose; they travel by day and by night on pick up goods trains, express goods trains and stopping passenger trains. They thus learn, under the direction of the train controller, not only the geography of the railway, but also the details of the duties of brakesmen and guards, and they take part in the sorting and classifying of goods, as well as in the various operations performed during journeys.

The *Technical Training Service* of the *Midi Railway* provides classrooms in which the staff is supplied with all the written matter necessary for instructional purposes and where it can obtain the advice and guidance of the experienced employees who are placed in charge of the classrooms.

Apart from these general measures, a certain number of special measures have been adopted by various railway administrations; we shall mention the most interesting, classifying them according to the category of staff to which they relate :

a) Employees of the active branches of the service other than train staffs.

In the case of the *Belgian National Railway Company*, employees of the traffic

service are required on engagement to attend theoretical and practical courses lasting for six weeks, with a view to acquiring rapidly the knowledge necessary for the performance of their duties; during this period such employees are exempt from all duties. Employees who fail to pass the examination which concludes the courses may be withdrawn from the traffic service.

On the *Paris-Orleans Railway* employees who have already received their training for work in the active branches of the service are given instruction relative to general railway organisation. This instruction is given during working hours, and is obligatory for the employees concerned. To supplement the lessons, the employees are then shewn the working of interlocking plant at stations and of signals and semaphores in a travelling instruction van.

Further, special courses have been instituted for the benefit of employees who have to deal with the settlement of claims, and whose duties necessitate a detailed knowledge of tariff questions and of the fundamental principles of commercial law in so far as it appertains to transport matters. These courses comprise a series of lectures dealing with the principal questions affecting the efficient organisation of transports : compensation payments, condition and packing of parcels, verification on departure, total or partial loss of goods, damage, searches, delays, matters in suspense, difficulties with taxation or customs authorities, method of collecting siding or warehouse charges, parcel post organisation, essential principles of international transport, etc. One of the lectures is illustrated by cinematograph films showing the good features and defects of the usual methods of packing. In addition, a correspondence course is arranged for bookkeepers and rates clerks, to keep them informed as to the latest modifications in rates and the method of their application.

On the *Paris, Lyons & Mediterranean Railway* each service district has its own local school, under the control of an inspector, for the training of employees of the traffic service (general messengers, correspondence messengers, etc.); the courses in these schools last for two months and are followed by an examination, on the results of which a decision is made as to what particular branch of the service the employees in question are best fitted to enter.

There are also other regional schools for shunters, porters, lampmen, etc. Their object is to improve the technical qualifications of the employees concerned, to ensure that they understand the regulations and to teach them the best methods of work.

Finally, at Paris, Dijon and Marseilles there is a regional traffic school, at which employees can acquire the elementary knowledge necessary to fit them to occupy the various posts in a station office.

On the *French Est Railway* young employees of the shunting service at large marshalling yards are distributed in groups under foremen shunters, who take advantage of the less busy periods to give instruction on the spot with regard to the shunting service in general and to the testing and adjustment of couplings in particular.

Lectures are also given on signaling : the lecturers have at their disposal small scale models of signals with which to illustrate their explanations.

Finally, other lectures are given, illustrated by cinematograph films, on the following subjects : handling of express and slow train goods; handling of goods

at intermediate stations; use of appliances such as the lamp yoke, coupling pole, the Vici crane (small 600-kgr. [1 320-lb.] crane used for the rapid handling of sealed wagons containing postal packets); films are also being prepared dealing with the operations of securing loads, trimming loads, roping, weighing, and verifying the loading gauge; the utilisation of rolling stock, the allocation of stock and wagon questions; making up loads for wagons or groups of wagons; method of use of loading appliances, shunting by means of engines, etc.

The *Algerian State Railways* are at present contemplating the creation of a « traffic school », to which such employees would be sent as appear likely to benefit by the courses which will be given.

b) Train staffs.

The *Belgian National Railway Company* has instituted special courses, lasting for three weeks, for the instruction of junior train staff.

On the *French Nord Railway* train staffs are required to attend for half an hour per month (counted as working time and so entered on the work sheets) at lectures given by train controllers. After the lectures, the lecturers question the listeners in order to ascertain that they have really assimilated the instruction given.

On the *Paris, Lyons & Mediterranean Railway* courses for train staff are given periodically in each railway section: general labourers receive training in the duties of train attendants and guards, and train attendants and guards in the duties of head guards.

c) Drivers and firemen.

The *Belgian National Railway Company* requires its engine staff to take theoretical and practical instruction in their particular duties; attendance is obligatory and must be for at least two hours per month. In addition there are optional special courses, comprising fifty lessons per annum; the instruction given in these courses covers all the technical and administrative questions relative to this particular branch of the service, and is supplemented by optional lectures given in « travelling instruction vans », which are specially equipped for the giving of practical demonstrations.

On the *French Nord Railway* drivers receive special instruction on the construction, working and maintenance of the various parts of the locomotive and accessory appliances; the possible sources of trouble and their remedy are indicated for each type of locomotive.

Lectures are arranged for drivers and firemen in which cases of breakdown or more serious accidents are commented upon in detail. These lectures are given outside working hours and attendance is optional; none the less they are attended by a large number of employees. By means of large scale diagrams, full or reduced scale models of the different parts of the locomotive or of the different signals, miniature locomotives which can be taken to pieces, and permanent way models fitted with miniature signals, lit by electricity and workable from a distance, practical demonstrations can be given.

The benefit derived from this instruction by drivers and firemen is tested by yearly examinations bearing on all aspects of the service; the examiner is given a slip showing what lectures the employee has attended, and can therefore judge, in case of need, whether the failure of an employee is due to neglect on his part

to take advantage of the instruction provided.

The *French Nord Railway* state that results obtained are excellent and that the regularity of the service is better than before the war.

On the *French Est Railway*, at every depot, five lectures of at least one hour each, and if possible two hours, are given each month : one on the regulations relating to signals, one on the regulations to be observed by drivers and firemen, one on general instructions, one on the component parts of locomotives and, finally, one on defects in locomotives.

The lectures on the regulations are given outside workshop hours in order to allow of the attendance of the workmen and labourers; the lectures on locomotive parts and defects, as they particularly concern drivers and firemen are given as far as possible during workshop hours, so that practical demonstrations may be given. These lectures are given by depot superintendents, and are followed by questions intended to ascertain whether the instruction given has been thoroughly understood and to afford an opportunity for supplementary explanation where necessary.

A record is kept of each employee's attendances at the lectures.

The employees are questioned periodically to test the results of the instruction given to them; the questions are put by head drivers, preferably in the course of actual work. Each employee must, in principle, be orally examined at least once each year upon the regulations relating to signals and the duties of drivers and firemen, upon general regulations and upon engine parts and defects.

Oral questions are also put by the higher depot officials and, for example, drivers whose answers are not satisfactory are placed on marshalling yard work or some other simpler duties; employees who are learning the duties of drivers are employed as firemen until the next following examination.

The *Paris, Lyons & Mediterranean Railway* provide their drivers and firemen not only with the actual regulations and instructions, but also with technical works, in both cases free of charge.

d) Train examination.

The *French Nord Railway* have instituted at Longueau a special school for train examining staff, to which all members of that staff are sent in turn for two weeks, in groups of 10 or 15; the theoretical instruction is supplemened by practical demonstrations given by means of apparatus provided for the purpose : apparatus demonstrating the action of the inner elements of an isothermos box; carriage frame comprising electric lighting installation, steam heating and brake; buffing gear; bogie frame.

The *French Nord Railway* report that since the opening of this school there has been a marked improvement in the inspection service.

On the *French Est Railway* candidates for appointment to the examination staff are taken from among the workmen and labourers of the Carriage and Wagon Department.

Only candidates who are under the age of 35 and whose education is up to elementary school standard can attend the special courses.

Candidates admitted to the courses are sent for three months to an instruction centre, where they take special theoretical and practical courses. The general programme is as follows :

1. Work in workshop (3 1/4 hours per

day): running repairs, fitting brasses to axle box and to the journal, care of Westinghouse brake, etc.

2. Theoretical instruction (45 minutes per day): general observations on examination work — rules to be observed as regards withdrawal for repairs of express and slow train rolling stock, instruction in regard to steam heating of trains, working and maintenance of the continuous brake, closing of doors, etc.

3. Practical instruction (4 hours per day):

a) *In workshops.* — Examination of express and slow train stock coming in for repairs, or, on leaving, inspection of parts and search for defects, special inspection of heating apparatus, etc.;

b) *In marshalling yards.* — Examination, under the guidance of an experienced examiner, of trains during marshalling or shunting, special inspection of continuous brake appliances, intercommunication apparatus, lighting equipment, examination of loads, etc.

The courses are given by a gang foreman and supervised by a higher official.

Two months after completing the courses, candidates take the regulation examination qualifying for appointment to the inspection staff, to which staff they are in due course appointed if they succeed in passing the examination.

On the *French State Railways* inspection staff candidates not taken from the ranks of the shopmen are obliged to serve a preliminary period of three months in a workshop in order to acquire that minimum of practical experience which is indispensable for the carrying out of the minor repairs which normally fall to the examination staff.

e) **Permanent way maintenance staff.**

On the *French Nord Railway* the gangs responsible for the maintenance work of a section are periodically brought together to work under the direction of a higher employee who supervises their work and explains the methods to be adopted to obtain the best results.

Similarly, the sectional foremen and under-foremen are brought together periodically to observe the repair and maintenance work of a gang chosen among the most efficient workers and working under the direction of a higher employee who describes and explains the best methods to be adopted.

During the bad weather of the winter season, the sectional foremen and under-foremen, together with such gangers as appear likely to become qualified for promotion, are sent to an instruction centre where they follow courses dealing with the installation of track appliances and signals, maintenance of the track and track appliances, repair of damage, care of tools, etc.

Each year three groups of 60 employees each pass through the instruction centre; the duration of the courses is three weeks.

It is proposed to prepare an educational film illustrating the technicalities of important permanent way work, as executed at various points of the railway. This will provide a means of giving employees a visual illustration of the best methods to be adopted for the execution of the work entrusted to them.

As regards the Electrical Department, in order to secure appointment employees must first undergo a period of training with gangs engaged on construction work, in order to learn the handling, installation and dismantling of the appliances;

they then spend a certain period in becoming familiar with the particular duties which they will ultimately have to perform; further, the more efficient of the employees engaged in the maintenance of electrical plant are assembled at certain periods of the year for the purpose of taking special courses in the workshops at Saint-Ouen; these courses deal with the subect of electricity in general, the methods of measuring electric energy, electric plant, etc.

As an experiment, certain employees of the Electricity and Lighting Departments were allowed to attend the practical course in lighting work held from January to April 1928 at the « Ecole spéciale des travaux publics », Paris; the fees for this course were borne entirely by the railway administration.

On the *French State Railways* special courses are arranged at the central workshop of the electricity and signals service for the benefit of the foremen, assistant foremen, and assistant inspectors of that service; these courses last for four weeks and cover the routine work of the service (soldered joints, twisted joints, detection of faults in cables, testing, measurement of current, etc.).

On the *French Est Railway* schools are provided in which employees of the permanent way service can learn the operations of cutting seatings, and shovel packing, and there are also schools known as testing and instructional schools.

The object of the woodworking classes is to train the sectional foremen, under-foremen and gangers in the handling of tools as to make them efficient in the redressing of timber sleepers and in the relaying or adjustment of longitudinal sleepers; these courses last for two weeks.

The courses in the so-called testing and instructional schools last from two to three weeks; their object is to complete the theoretical and practical knowledge of the foremen, under-foremen and gangers and to initiate them into the methodical organization of the work of a section; the students take turns in controlling the work of the school's practice section, under the supervision of instructors who correct any errors that may occur in the course of work and give any necessary explanations.

There is also at Pantin a finishing school for employees of the electricity service; the courses comprise both general and technical instruction and last for one month (in one or two parts); by means of electrical apparatus and a model section of track equipped with different types of signals, practical demonstrations can be given in the detection of faults, the installation of apparatus according to plans, etc.

Finally, courses of instruction in the preparation of plans on the actual site of work are arranged each year for those district foremen and line inspectors who are capable of deriving benefit therefrom; these courses, which are obligatory for candidates for the grade of district foreman, comprise from four to six lessons of four hours each.

Candidates for the grade of « district foreman » in addition to attending the foregoing courses, receive instruction in all the subjects of the syllabus of the competitive examinations and tests which qualify for that grade, as well as in all the technicalities, a knowledge of which is essential to employees of that grade; the courses comprise from eighteen to thirty-four lessons of from two to three hours each.

f) **Office staff.**

On the *French Nord Railway* employees in the permanent way maintenance service offices are sent each winter to the instruction centre referred to above; the courses, which last a month, cover the following subjects :

— permanent way and permanent way fittings;

— safety appliances;

— hydraulic installations;

— bookkeeping, contracts, orders, etc.

On the *Alsace-Lorraine Railways* lectures are arranged for the staff which deals with the maintenance of safety appliances : models of the safety appliances are provided for the use of the lecturers. The use of travelling « instruction cars » and cinematograph films is at present under consideration.

On the *French Est Railway* correspondence courses dealing with questions of a general or practical nature are arranged for copyists of the permanent way service who are preparing for the examination qualifying for the grade of clerk.

Courses in draughtsmanship are arranged at the divisional centres for the benefit of draughtsmen and of tracers who desire to become draughtsmen.

Draughtsmen are also required to attend the above-mentioned courses of instruction in the preparation of plans on the actual site of work.

We will mention finally :

a) the measures adopted by certain railways for teaching foreign languages to those employees whose work brings them into contact with the travelling public. In 1928, for example, on the *French Nord Railway* about a hundred employees from the stations at Paris, Etaples, Boulogne, Calais and Dunkirk, and from train staffs, received fifteen lessons of one hour each, in the course of which they learned sufficient of the rudiments of English to be able to give information to passengers.

b) the measures adopted by the *Alsace-Lorraine Railways* for instructing the staff in the French language : about one hundred professional teachers are engaged in giving elementary lessons to employees who have no knowledge of French, and more advanced lessons to those who already have some knowledge of the language. At the more important railway centres libraries are placed at the disposal of the staff.

We have inquired, further, whether there exist on the various railways and in the various branches of the service, organizations whose duty it is to determine the best methods of working. It would indeed appear desirable, in an industry so well established as the railway industry, where the operations to be performed are generally unvarying and constantly repeated, to determine the best, the most expeditious and the most economical methods. A saving of time, however slight, on any given operation may, as a result of the constant repetition of that operation, result in a very considerable total saving.

In this connection we have received the following information :

On the *French Nord Railway* a commission consisting of three chief engineers (one for each main branch of the service) has recently been created for the purpose of determining the best methods of working. It is assisted by a subcommission, also composed of three members.

Three further commissions function

respectively for carriage repair, wagon repair and construction work. The third of these commissions is divided into three sub-commissions, dealing respectively with metal working, timber working and saddlery. These commissions are composed of responsible employees from the repair and construction shops.

The *Belgian National Railway Company* has instituted :

for the Operating Department : a commission whose duty it is to study the operations which take place in important stations with a view to discovering defects in the organization and the most suitable means of remedying them;

for the Permanent Way Department : a commission presided over by a chief engineer, assisted by engineers and technical inspectors, who are in constant touch with the employees in charge of the maintenance of the Company's lines. The methods of working are discussed at meetings at which are present not only the members of the commission but also delegates representing employees of the service; new methods are not introduced until they have been tried out on various parts of the line;

for the Chief Mechanical Engineer's Department : a commission, presided over by an engineer in charge of a section, assisted by engineers, sectional superintendents, foremen, draughtsmen and workmen, considers the best methods of working to be applied in the repair and maintenance of rolling stock. This commission pays particular attention to the improvement, by the adoption of modern and scientific processes, of the existing methods of working; it publishes about once a month a report dealing with the more interesting cases of rationalization of working organization.

Several years ago the *French Est Railway* instituted a department for the rationalisation of marshalling yard organization : this department has reorganized the principal yards of the railway system, introducing into each the best methods and the most suitable equipment. The results obtained have been excellent : the capacity of the yards has been increased by about 50 %, and it has been possible to avoid the construction of several new yards, the provision of which had hitherto appeared indispensable.

Further, at the main workshops at Epernay a works organization bureau has recently been installed, one section of which is specially commissioned to ascertain the best methods of doing work and to draw up instruction sheets for the purpose of explaining these methods to the workmen. The most rapid methods are determined by exact timing.

Certain railways have a special service for the supervision of the staffs of stations, workshops, etc. This service, having to determine the number of employees required for each establishment, makes a detailed analysis of the whole of the work to be performed and, in doing so, is naturally led to seek and to generalize the best methods.

We have also endeavoured to ascertain the methods adopted for ensuring that the staff knows and understands the regulations. On the majority of the railways this is done by periodical oral questioning, in certain cases once a year and in others only prior to promotion to a higher grade; in other cases the questioning is done by responsible officials (inspectors, etc.) as opportunity offers in the course of their rounds of inspection.

On all railways the regulations are edited by officials not specially engaged in their preparation.

V. — Training of staff for promotion to higher posts.

Having examined the methods adopted for imparting to employees of the various categories the knowledge which is essential for the performance of their own work and that of those employees with whom they may work jointly, we shall now examine the special measures taken by certain railways for preparing employees for promotion to higher grades.

The most interesting cases are mentioned below :

Advanced School of Train Operation of the Paris, Lyons & Mediterranean Railway.

The Paris, Lyons & Mediterranean Railway founded in 1921, at Dijon, a school for the preparation of employees of the Department for promotion to the posts of 1st class Stationmaster and Inspector, by giving them a complete course of professional training and familiarising them with the problems likely to be met with in practice.

This school is controlled by an official of the grade of Assistant Chief Inspector.

The pupils are chosen from among the more promising assistant stationmasters or young stationmasters; in particular all pupils from the Public higher schools must take these courses before the end of their third year of service. The courses are also taken by those assistant stationmasters who are employed as dispatchers and are likely to become chief dispatchers.

The courses last three months. In principle the morning sessions are devoted to lectures upon questions concerning station work : passenger and luggage service, organization of express and slow goods traffic, the internal organization of stations and the train staff service, utilization of staff; courses are also given bearing on the allotment of rolling stock, traffic, signals, interlocking plant, telegraphy, lighting, engines, rolling stock, continuous brake, etc.

The afternoon is devoted to practical work, visits to stations and signal boxes, and demonstrations of the apparatus used.

During the remainder of the time the pupils have free access to a reading room supplied with a collection of the regulations, circulars and instructions which they may require, together with wall charts containing information in regard to signals, rolling stock, continuous brake, etc.

At the end of the courses the pupils sit for a final examination and are classified according to the marks obtained.

Advanced School for the Traffic Service of the Paris, Lyons & Mediterranean Railway.

In 1923 the *Paris, Lyons & Mediterranean Railway* also founded, at Lyons, a school of advanced instruction for employees of the traffic service. This school is under the control of an Inspector, who devotes his whole time to this work.

The object of the school is to complete the training of responsible employees of station offices or of promising employees of the outside or central services : at the end of the courses employees who have passed the final tests are allowed to take the examination qualifying for promotion to the higher grades of the traffic service, just as their colleagues who have successfully passed through the courses of the Train Operation School can take the examination qualifying for promotion to the higher grades of the operating service.

The pupils are chosen among former pupils of the « Grandes Ecoles » (high schools); employees holding diplomas of the « Ecole des Hautes Etudes Commerciales » (School of Advanced Commercial Studies) or of the commercial schools; or holding degrees in law; as well as from among employees who have shown particular ability in station work or in their studies at a regional traffic school.

The duration of the courses is three months. The syllabus covers all questions concerning the traffic service. Lectures are given on the tariffs applying to passengers and goods, on legal proceedings in connection with transport questions, on the system of bookkeeping adopted at stations, and on the use of publicity for increasing traffic. The pupils are also given instruction in the economic geography of the railway and the main movements of merchandise in which it participates.

Finally, advantage is taken of the opportunity afforded by visits to certain selected stations to carry out practical exercises illustrating the instruction given in these lectures.

As in the case of the Operating Service School, the pupils take an examination on leaving, and are graded according to the marks obtained.

Advanced School of the French State Railways at Rouen.

The *French State Railways* have at Rouen an advanced school for the Railway Operating Service for the preparation of employees for the higher station posts. Candidates are selected by examination from among middle grade employees of all branches who are physically fit to occupy posts connected with the safety of the service, who have occupied a station post for at least two years and who hold either certain diplomas or a special certificate of efficiency issued by the railway.

The examination is designed to test whether the candidates have acquired the knowledge which it is necessary that responsible station employees should possess in regard to traffic, signals, regulations, goods service (tariffs and claims) and verification of receipts.

The instruction given in the school covers all branches of the service (traffic, shunting, signals, regulations, tariffs, claims, verification and recording of receipts, general administration, staff, recording of expenditure) and all questions connected with the rolling stock, traction and permanent way services with which a responsible employee in the outdoors section of the operating service must be familiar.

The instruction is given by means of :

a) lectures in which it is endeavoured above all to emphasize the general principles which underly the regulations, instructions, etc., while explaining the theories and methods of working in force at the moment and their reasons;

b) demonstration visits to illustrate the instruction given in the lectures;

c) practical work to accustom the pupils to take charge and to give them practice in the solution of the problems arising in the course of work;

d) written exercises and questions relating to the regulations and instructions as well as to the subjects taught in the courses.

The object of the instruction is not only to develop the pupils' knowledge but also to fit them to act in turn as instructors of the junior staff.

The courses last for three months.

The instruction is given by instructors chosen from among railway officials, generally of the rank of divisional inspectors.

There are in principle two series of courses each year : for each series the maximum number of pupils is 35.

At the end of the courses the pupils take a leaving examination and, if successful, are given a school certificate specifying the results obtained. These certificates are taken into account as regards the subsequent promotion of the employee.

Advanced technical courses of the French Est Railway.

These courses are intended for the training of employees to hold responsible posts in the workshops. The are divided into two sections : one for locomotive workshops and the other for rolling stock workshops.

The pupils are taken from among former apprentices and former pupils of the State technical schools; these young people must be in their first trial year after completing their military service.

With a view to their admission to the advanced technical courses, youths who have completed their apprenticeship and who are considered capable, after their military service, of following these courses, receive each month a series of questions on mathematics, mechanics, technology and electricity. They must answer these questions with the help of the printed matter which they have or can obtain. The answers prepared by the pupils during the month are examined during the following month and returned to them with corrections and annotations.

The course lasts for one year in the case of the rolling stock section; in the case of the locomotive section the course comprises nine months in the workshops at Epernay and three months at a locomotive depot.

The syllabuses include :

a) General instruction : revision of 2nd and 3rd year apprenticeship courses, mathematics, mechanics, technology, electricity, plans, composition of letters and reports.

b) Technical instruction : knowlegde of the regulations, the organisation and safety of working, manual work, periods of practical work with the various gangs.

c) visits to workshops under the guidance of an instructor.

In order to qualify for admission to the advanced technical courses, pupils must pass a preliminary examination. At the end of the courses those who have obtained satisfactory results receive a bonus and are presented with a certain number of technical books to enable them to continue their studies; they are then allotted to posts in which they can make use of the general training they have received. Each of them is the subject of a special report and those who have shown that they possess the necessary qualities are marked for promotion to posts of responsibility.

Training courses of the locomotive running service of the Paris-Orleans Railway.

The *Paris-Orleans Railway* has organized, for those grades of traction service employees who desire to prepare for posts of responsibility, training courses for developing their general and technical knowledge. In order to render them more accessible to the travelling staff, these courses are given by correspondence; the syllabus varies according to the branch of the service (depot, workshop, etc.) to which the pupils belong.

The instruction is spread over thirty

months, during which the pupils (who are allowed to take the courses only after passing a preliminary examination) receive each month, on a fixed date, the matter to be studied and the exercises to be worked.

An adequate equipment of apparatus is provided, in an instruction car, for the use of those employees who are detailed to examine the pupils periodically or to give them lectures.

Courses at the « Ecole des travaux publics », Paris.

The *Great French Railways* have adopted various measures for providing special instruction in railway work for those of their employees who appear likely to profit thereby. This instruction is given by the « Ecole des travaux publics », Paris, partly in oral courses and partly by correspondence.

a) *Oral courses.* — Most of the railways have participated recently in the creation of a « Railway section » at the « Ecole des travaux publics », to which promising middle grade employees will be sent for the duration of the courses (nine months per annum) for the purpose of developing their general education and perfecting their technical knowledge. The instruction given during the first three months will relate to matters common to all branches of the service; during the remaining six months the instrucion will be specialized for the different branches. The courses of general instruction will be conducted by professors of the « Ecole des travaux publics »; the technical instruction will be given by higher railway officials.

b) *Correspondence courses.* — On the *Paris, Lyons & Mediterranean Railway* these courses are available :

1) for employees of the permanent way service who are candidates for posts as district superintendents and sectional superintendents;

2) for employees of the locomotive running service who are candidates for the post of assistant depot superintendent.

At the end of the courses preparing for the post of assistant depot superintendent — which last for 18 months — an engineer of the Company assists the board of examiners in giving the final examination; those employees who pass this examination and obtain the certificate are marked as « attached to traction service » and are eligible for promotion to the post of assistant depot superintendent.

In the case of success in the final examination, the railway administration reimburses the successful candidates for the total examination fees and half the expenses incurred by them in taking the course.

On the *French Nord Railway* the correspondence courses of the « Ecole des travaux publics » are available to employees who are preparing for the posts of assistant stationmaster or deputy stationmaster; at the end of the courses — which also last for 18 months — the employees take an examination and if they are successful the railway administration reimburses to them all or part of the fees for the course and examination.

We shall mention finally the creation by the *Paris, Lyons & Mediterranean Railway* in January 1929 of a periodical review, for the purpose not only of instructing the staff but of keeping it informed as to matters connected with railway work in general and with that of the

Paris, Lyons & Mediterranean Railway in particular.

The General Manager of the Paris, Lyons & Mediterranean Company, in a preface to the first number of the review, states :

« Better than the books of a library, because more up-to-date, more widely diffused and more easy and pleasant to read, this Review, which will appear every two months, will enable those who desire to gain instruction to develop their technical knowledge gradually and without difficulty, while extending their general education, given the diversity of the subjects which will be dealt with.

« It will provide information as to the latest developments in the different branches of the service, on traffic conditions, on the improvements effected in each sphere of activity and even in some cases on points of detail, for the Paris, Lyons & Mediterranean Review, being intended for all, will willingly accept the collaboration of all parties upon every variety of subject.

« It will, further, as far as possible, publish lists of appointments, and will record the acts of courage and devotion so frequently performed by railway employees. »

The review contains some twenty pages. We cannot do better than give a summary of the first number — the only one which had appeared at the date of preparation of the present report. The subjects dealt with are as follows :

After enumerating the appointments and promotions as at 1st January 1929, and the awards granted as at the same date, there follow the prefatory remarks of the General Manager of the Paris, Lyons & Mediterranean Company from which we have given extracts above, after which there are articles giving details in regard to the new line from Nice to Coni, on the agricultural service performed by the Paris, Lyons & Mediterranean Company and on its participation in the Lyons Fair of 1928, and, finally, on the inauguration of the Casablanca- Marrakech line and on the railways of Morocco. These articles are illustrated by maps and photographs. Following these articles there is a graph showing the average number of wagons loaded on the Paris, Lyons & Mediterranean lines per day for each week from 21st October to 15th December 1928.

This Review should prove a most useful and interesting source of information.

Appendix I

Questionnaire adressed to the Administrations mentioned in Appendix II.

Question 1.

By what means do you ensure that the staff engaged by you has had adequate previous training?

a) What are the posts which you fill directly by the appointment of outside candidates?

Are you required to restrict the appointment of outside candidates to the lower posts, or are you allowed to make such appointments to the middle and higher posts?

b) What are, from the point of view of training, the conditions to be fulfilled for admission to each of these posts? (You are requested to attach, if possible, syllabuses of examinations or tests which candidates must undergo, or to state the diplomas which they must possess.)

In the case of posts for which certain natural qualities of observation, coolness, rapidity of decision, etc. are particularly desirable do you arrange for tests whereby you can discover those candidates who are specially endowed with these qualities and eliminate those who do not possess them?

What are the tests for each of the posts in question?

Whom do you appoint to conduct the tests?

Question 2.

Do you require professional apprenticeship?

If so :

a) What are the occupations for which you train apprentices?

b) What is, in normal times, the yearly number of vacancies allotted to each such occupation ? The number of apprentices trained yearly ?

c) How do you engage your apprentices? What conditions must they fulfil to qualify for apprenticeship? In particular, are candidates required to pass an examination? If so, please give the syllabus of examination.

d) Are your apprentices indentured? If so, please attach a copy of the indentures.

e) How are the apprentices grouped during their apprenticeship? Where do the various groups receive their training?

f) What training is given to them?

Is their professional manual training supplemented by theoretical instruction or even by some general education?

Please give for each category (drivers, joiners, electricians, etc.) the training syllabuses and the period of training.

g) By whom is the training given?

h) How do you control the training of your apprentices? What examinations are they required to take? Are their parents kept informed as to the progress made? Do you give diplomas at the end of apprenticeship?

i) Are the apprentices remunerated in cash or in kind during their apprenticeship? If so, please state the nature of such remuneration.

j) In the cases of apprentices who obtain sufficiently high marks, do their indentures entitle them, on the termination of apprenticeship, to employment on the railway, or is such employment merely given as a matter of custom ?

Question 3.

In the case of employees other than workmen, what methods do you adopt in order to secure a sufficient number of candidates possessing a satisfactory standard of education ?

Do you, for example, grant subsidies to, or have you entered into agreements with certain schools ? If so, please state the amount of the subsidies or the nature of the agreements, and the approximate number of candidates obtained yearly from such schools.

Question 4.

What methods do you adopt for improving the qualifications of the existing staff?

Please state the methods adopted for each main category of staff and, in particular, for the following :

Traffic Department staff.
Train staff.
Drivers and firemen.
Inspection staff.
Permanent way maintenance staff.
Repair and maintenance staff for locomotives, tenders, carriages and wagons.
Technical office staff.
Administrative office staff :
Bookkeepers.
Shorthand-typists.
Other staff.

Please give a *separate reply for each of these categories* to the following questions :

a) Does any organisation exist for the purpose of determining the best methods of work? If so, please state how this organization is composed and how it works.

b) What are the methods adopted :

1. to develop the technical knowledge of the staff;

2. to ensure that it knows and understands the regulations;

3. to teach it the best methods of work.

Issue of printed instructions?

Individual teaching by the more experienced employees?

By the immediate department head ?

Collective teaching by lectures or practical demonstrations?

c) By whom are the printed instructions drawn up which are used in the instruction of the staff? Are there officials who specialize in the preparation of such documents?

d) If the instruction is given by means of lectures, please indicate by whom and under what conditions they are given; if attendance at these lectures is obligatory or optional, and whether they take place during or outside working hours.

Please indicate any interesting features of the practical instruction (demonstration apparatus, demonstration vans, use of cinematograph, etc.).

e) What methods are adopted for superintending the instruction of the staff and ensuring periodically that they are making satisfactory progress, particularly as regards knowledge of the regulations?

f) What are the results obtained?

Question 5.

What are the methods adopted for preparing staff for the higher appointments and particularly for enabling them to attain managerial posts?

APPENDIX II.

List of Administrations to whom the Questionnaire was addressed with a view to the preparation of the report.

Belgium.

*Belgian National Railway Company.
*French Nord Railway (Nord-Belge lines.
*Bas-Congo - Katanga Railways.
Chimay Railway.
Malines-Terneuzen Railway.
Light Railways of Liége-Seraing and extensions.
Belgian Railway and Industrial Company.
Congo Railway Company.
General Light Railway Company.

Spain.

*Andalusian Railways.
*Central Aragon Railway.
*Madrid-Saragossa Railway.
*Medina del Campo-Salamanca Railway.
*Medina del Campo-Zamora Railway.
*North of Spain Railway.
Catalonian Railways.
Madrid—Cacérès Railway.
Mines and Railways of Utrillas.
Great Southern of Spain Railway.

France and Colonies.

*State Railways. — *Algerian State Railways.
*Alsace-Lorraine Railways.
*Est Railway.
*Midi Railway.
*Nord Railway.
*Paris—Orleans Railway.
*Paris, Lyons and Mediterranean Railway. — *Algerian Railways of the Paris, Lyons & Mediterranean Company.
Cambrésis Railway.
*Tarn Departmental Railways.
*South-Western Railways.
*Compagnie générale des Chemins de fer vicinaux.
*Société des Transports en Commun de la Région parisienne.
*Tunisian Railway Company.
*Colonial Railways of French West Africa.
*Port de la Réunion Railways.
*Dahomey French Railway Company.
Ethiopian Railway from Djibouti to Addis-Abeba.
*Damascus—Hama Railway.
*Smyrna—Cassaba Railway and extension (Syria).
Paris Girdle Railway.
Chauny—St. Gobain Railway.
Departmental Railways.
Bouches-du-Rhône Railway and Tramway Administration.
Société générale des Chemins de fer économiques.
Northern Light Railways Company.
Eastern Railways of Lyons.
Landes Railways.
North-Eastern Secondary Railways Company.
Somain to Anzin and the Belgian frontier Railway.
Provençal Railways.
Local Light Railways Company.
Ain Department Tramways.
Deux-Sèvres Departmental Tramways.
Indre Tramways.
Gafsa Railway.
Dakar—St. Louis Railway.
Colonial Railways of Indo-China.
French Indo-China and Yunnan Railway Company.

(1) The Administrations marked with the sign * replied to the Questionnaire; the remaining Administsrations sent no reply.

Italy.

State Railways.
Mediterranean Railway.
North of Milan Railway.
Emilian Railway, Tramway and Automobile Company.
Venetian Company for the construction and operation of secondary railways in Italy.
Central Apennine Railway.
Canavese Central Railway and Tramways.
Reggio—Emilia Railway.
Sardinian Auxiliary Railways.
Suzzara—Ferrara Railway.
Tessin Railway.
Tramways of Lombardy and Romagna, Brescia-Mantua-Ostiglia-Desenzano and Forli-Meldola-Forli-Ravenna-Classe Tramways.
National Society of Railways and Tramways.
Interprovincial Steam Tramways of Milan-Bergamo-Cremone.
Steam Tramways of Piedmont.
Steam Tramways and Light Railways of the Province of Pisa.
Rome-Milan-Bologna Tramways and Light Railways.
Sicilian Company for Public Works (« Circum-Etna » Railway).
Lombardy Electric Traction Company.
Turin Tramway and Light Railway Company.
Vercellesi Tramways.

Netherlands.

*Netherlands Railway Company.
*Dutch East Indies Railway Company.
Dutch Railways.
Breskens — Maldegem Steam Tramways.
Steam Tramways of the South Netherlands.
Dutch East Indian State Railways.
Semarang — Cheribon Stean Tramways.

Portugal.

*Portuguese Railway Company.
State Railways (European and Colonial).
Portuguese Railways of Beira-Alta.
National Portuguese Railway Company.

Affiliated Organisations.

*International Sleeping-Car Company.
International Auxiliary Railway Company.
Fascist National Confederation of Land Transport and Inland Navigation (Italy).
Railway and Automobile Transport Union.
International Railway Union.

APPENDIX III.

Duration of training periods on the various French railways for candidates holding certain diplomas.

N. B. — The principal diplomas are the following :

Group I.

Ecole Polytechnique.
Ecole Centrale de Paris (Engineers of Arts and Manufactures).
Ecole Supérieure des Mines de Paris (Civil Mining Engineers).
Ecole Nationale des Ponts et Chaussées (Civil Engineers for Bridges & Highways).
Ecole d'Application du Génie Maritime.
Ecole des Beaux-Arts (Architects).

Group II.

Bachelors of Science and of Arts.
Ecole Supérieure d'Electricité (Electrical Engineers).
Ecole des Beaux-Arts (Students' 1st class diplomas).
Ecole des Sciences Politiques.

Group III.

Instituts Electrotechniques et Mécaniques at Lille, Nancy, Grenoble and Toulouse (Electrical Engineers).
Institut Industriel, Lille (Mechanical Engineers).
Ecole spéciale de Travaux Publics (Higher diplomas).
Ecole Centrale de Paris (Certificate of proficiency).
Ecole Nationale d'Arts et Métiers and Ecole libre d'Arts et Métiers, Lille and Rheims (Engineer's diploma).
Assistant Engineers of the Public Works and State Services (Bridges and Highways or Mines).
Doctors of law.

Group IV.

Ecole Nationale d'Arts et Métiers and Ecoles libres d'Arts et Métiers, Lille and Rheims (Students' diplomas).
Candidates for posts of Assistant Engineers of the Public Works and State Services (Bridges and Highways or Mines) admitted to the written tests of the examination for the grade of Assistant Engineer.

Alsace-Lorraine Railway.

Employees admitted to the Chief Mechanical Engineer's Department.

	Groups I & II. Months.	Groups III & IV. Months.
Period in depot. . . .	2	2 ½
— on engines . .	1	2
— in a large workshop :		
in outside department	12	17
in offices. .	2	2
— in workshop for apprentices	1	1

Employees admitted to Locomotive Running Department.

	Groups I & II. Months.	Groups III & IV. Months.
Period in depot. . . .	2	4 ½
— in depot offices	1	1
— in workshop.	4	4
— on engines :		
as fireman	6 ½	7
as driver. .	6	18

State Railways.

Employees admitted to Chief Mechanical Engineer's Department.

(Groups I to IV.)

Period in carriage repair shop	4 months.	
— in engine repair shop	7	—
— in traction depot. . .	1	—
— in administrative office	2	—
— in receiving section of workshops . . .	4	—

Employees admitted to Locomotive Running Department.

(Groups I to IV.)

Period in large workshop. .	3 months.	
— in depot	3	—
— on engines :		
as fireman	4	—
as driver	8	—

Nord Railway.

Special training periods are laid down only for employees of the Locomotive Running Department.

Groups I and II.

Period in depot workshop	1 to 2 months.	
— in engine —	2	—
— on engines.	2 to 3	—
— as assistant depot superintendent (supernumerary)	1 to 2	—
— attached to Operating Department Inspector.	6 weeks.	
— attached to Engineer	2	—

Groups III and IV.

Period in depot workshop. .	4 months.	
— in engine — . .	2	—
— on engines :		
as fireman	12	—
as driver.	14	—

Paris-Orleans Railway.

	Group I. Months.	Group II. Months.
Period in large workshop in active service	2	3
— in offices . .	6	6
— on engines :		
as fireman.	3	5
as driver. .	1	3
— as assistant to head driver	3	3
— in depot . . .	6	6
— in the operating department	1	1

Employees in the Carriage and Wagon Department.

	Groups III & IV
Period in workshop	6 months.
— in maintenance . . .	2 —
— on engines	(period varies).
— as foreman of gang.	do.

Employees in the Locomotive Running Department.

Period in depot workshop. .	7 months.
— in large workshop. .	3 —
— in maintenance. . . .	2 —
— on engines	(period varies).

Paris, Lyons & Mediterranean Railway.

	Group I.	Group II.	Group III.	Group IV.
Period as workman.	4 months.	4 months.	3 months.	4 months.
— as fireman	3 —	3 —	4 —	6 —
— as driver-learner	—	3 —	3 —	6 —
— as driver	12 —	15 —	18 —	—
— as probationer (Scale 6*bis*)	4 —	6 —	6 —	—
— — (Scale 11).	—	—	6 —	—

Midi Railway.

Employees holding diplomas undergo in the first place 6 months' training in the workshops. They then pass to the Locomotive Running Department, where they act as firemen and then as drivers for periods which vary according to their ability.

Est Railway.

Employees holding Group II diplomas are not required to undergo any preliminary periods of training. Those holding diplomas of Groups I, III and IV undergo in the first place a period of training of :

2 months in a depot workshop,
2 months in the engine shops at Epernay;

then they are passed on either to the rolling stock service or to the Locomotive Running Department, or to other special services, where they pass through the stages indicated below :

Locomotive Running.

	Group I.
Period on engines :	
as fireman	3 months.
as driver	4 —
— in depot workshop. .	2 —

Carriage and Wagon.

Period on engines	1 —
— in large workshop. .	6 —
— in a rolling stock section	1 —
— on inspection work .	1 —

Employees intended specially for workshops at Epernay.

Period on engines :	
as fireman	3 months.
as driver	4 —

	Group I.
Period in workshops at Epernay (engines).	2 months.

Employees intended specially for the Designing Office.

Period in workshops at Epernay (engines).	3½ months
— on engines	1 —
— in a main wokshop .	3½ —
— on inspection.	1 —

Locomotive Running.

	Group III. Months.	Group IV. Months.
Period in depot workshop	4	5
— in workshops at Epernay (engines) .	2	2
Period on engines :		
as fireman.	8	10
as driver .	10	13

Carriage and Wagon.

	Group III. Months.	Group IV. Months.
Period in a gang. . .	4	5
— as assistant foreman of gang	8	10
— as assistant chief foreman	12	15

APPENDIX IV.

Note on the psycho-technical selective tests adopted by the Société des Transports en Commun de la Région Parisienne.

The *Société des Transports en Commun de la Région Parisienne* has organised a scheme of psycho-technical selective tests for apprentices for training as drivers and conductors and as skilled workmen, with a view to selecting those candidates who are the most capable and eliminating those who do not possess the requisite abilities.

The psycho-technical tests are given after the medical examination which precedes appointment and after the general education examination.

Later on, during their period of service, the conductors and drivers undergo further periodical medical examinations, supplemented by psycho-technical tests, to ensure that there has been no falling off in their technical abilities.

As regards apprentices, the tests imposed are the following :

1. Driver apprentices.

Diffused attention test.

This test is intended to measure the response, by definite, exact and rapid reactions, to variable stimuli.

The subject is placed in a dark room before a screen on to which a film is projected giving the subject the impression of being in the place of a driver on a running vehicle.

Around the screen are lamps of various colours (green, red and white) which light up alternatively in series of the same colour.

On the appearance of one or the other of the colours, the subject must press a certain pedal.

This test is followed by another in which the appearance of the different colours coincides with the ringing of bells of different tones.

The tests are then repeated, the pedals being replaced by handles.

The stimuli (lighting up of lamps, bells) and the reactions of the subject are registered automatically on a revolving cylinder.

Motor reactions test.

The purpose of this test is to measure the rapidity and regularity of the subject's reactions on hearing a sound.

The subject, having been placed in the same dark room as for the preceding test, is given an electric contact which he must press as soon as he perceives the sound; the pressures on the contact are registered on a revolving cylinder.

The sounds emitted (ringing of bells of different tones, etc.) are also registered.

The time elapsing between the stimulus and the reaction is measured on the cylinder.

Motor suggestibility test.

Motor suggestibility is a lack of muscular independence which prevents the subject from arresting as quickly as he should a movement already entered upon.

The absence of suggestibility characterizes the good driver. It is measured by means of the Binet apparatus.

This apparatus consists of two V. shaped wheels placed in the same vertical plane, with parallel axes, and connected by a slightly elastic endless belt.

Each of the wheels is fitted with a style and a handle. A cylinder revolves in front of the two styles.

The operator, by means of the handle, turns one of the wheels in such a manner that the style on that wheel follows a broken line which has been traced beforehand on the cylinder.

The subject, having previously been blindfolded, holds the handle of the other wheel and must endeavour to follow as exactly as possible the movements which, by means of the connecting belt, are imparted by the operator.

The movements of the second wheel are recorded on the cylinder. It is then easy to see the divergence between the line traced by the subject and that followed by the operator.

Localised muscular force test, or test for motor fatigue, measured by the Henry dynamograph.

The Henry dynamograph consists of a glass tube held in the vertical position, the lower end being fitted with a rubber bulb.

The bulb and about three-quarters of the tube are filled with mercury, on the surface of which there is a small float, the movements of which are recorded on a revolving cylinder.

The subject must exert pressure on the bulb and maintain the pressure as constant as possible during the test; the variations in pressure are recorded on the cylinder.

Estimation of speeds and distances.

The subject must guess the meeting point of two movable bodies moving at different speeds on a graduated scale.

Rapidity of perception of objects.

Images of simple objects or words are shown rapidly on a screen and the subject must recognize or read them as they pass.

Emotivity test.

Experience shows that a sudden emotion varies the electric resistance of the human body; the more emotional the subject, the greater the variation.

The test consists in interposing the subject in an electric circuit and submitting him to a sudden emotion; a galvanometer records the variation in electric resistance consequent upon the emotion.

This test is most valuable, as undue emotivity is dangerous to the safety not only of the driver but also of passengers.

Memory test.

This test consists in pronouncing slowly and at the same speed for each subject a series of associated words, two by two, sometimes antithetic, sometimes synonymous, sometimes having the same consonance, sometimes expressive of cause and effect.

When the whole list has been given, the subject is given the first of the two words in each series; he is then required to give the second word. A record is made of the errors and omissions.

Logical intelligence test.

The subject is given a series of disparate objects with which he must reconstitute a given geometric figure.

In classifying the subjects, account is taken of the fact that very marked superiority in one mental or motor function compensates for relative inferiority in certain other functions. If, however, this inferiority is excessive, the subject must be eliminated.

2. Conductor apprentices.

In addition to motor reaction tests, localised muscular force tests and memory tests, which are the same as for

drivers, conductor apprentices undergo the following special tests :

Test in distinguishing different coins.

The subject, having previously been blindfolded, is handed a bag from which he must take out in a given order discs representing 2 franc, 1 franc and 50 centime pieces.

Test in estimating number of passengers.

Views are shewn for very short periods on a screen, representing the standing room at the rear of a tram, the number of persons standing there being different each time; the subject is required to estimate the number of passengers in each case.

Memory for faces.

The subject is shewn a series of 50 portraits: these portraits are supposed to represent passengers, of whom a certain number only have purchased their tickets; these are indicated as each portrait is shewn.

The portraits are then shewn for a second time, and this time the subject is required to indicate those passengers who have not purchased tickets.

Logical intelligence.

The subject must reply in writing to á certain number of questions which have been drawn up by specialists.

Practical intelligence.

A certain number of trays are prepared, having holes of different shapes. The subject is required to insert the necessary pieces to fill all the holes.

The speed with which the subject completes the test is recorded.

3. Workmen apprentices.

Workmen apprentices, in addition to motor reaction tests, localised muscular force tests, memory tests, logical intelligence tests and practical intelligence tests, as described above, and, further, a technical test in which note is taken of the rapidity and precision with which it is carried out, undergo the following tests :

Manual ability test.

This test comprises the screwing of a series of nuts of different dimensions on to corresponding bolts, the sorting of beads of different colours, the insertion (the subject having previously been blindfolded) of plugs of wood of different sizes in holes of corresponding diameter bored in a plank of wood, etc.

The subject is classified according to the time taken and the mistakes made.

Attention test.

In this test the subject is required to cross out from a series of signs those which are of a given form.

Turner's test.

The apparatus consists of a lathe saddle fitted with two handles, one giving vertical displacement and the other horizontal displacement of the saddle. An arm fixed at the upper part carries two styles. With the first, and by means of the two handles, the subject is required to follow a circumference traced in advance; the second style inscribes the line traced by the subject. A note is made of the time taken and the errors in the line so traced.

Fitter's test.

The instrument used in this test is similar to a file with handle, so arranged as to slide in a frame. The subject imitates the movements of filing, and the precision of his movements is recorded by means of two styles, one fixed at each end of the file.

APPENDIX V.

Note on apprenticeship in the Chief Mechanical Engineer's Department of the French Est Railway.

I. — Engagement.

Conditions of admission. — Candidates are selected at the beginning of October each year by means of an examination.

Candidates must be of French nationality, be not less than 13 years 9 months and not more than 17 years 9 months of age on the 1st October of the current year, and be free of any obligation towards any firm with which, they may previously have commenced an apprenticeship. It is not essential that they should be related to an employee of the Company.

In exceptional cases the age limit may be lowered to 13 years as at the 1st January following the examination, for youths who hold an elementary school certificate and are of sound physique; or it may be raised beyond 17 years 9 months in the case of youths who have received a higher education (technical or secondary school pupils).

Applications for engagement must be countersigned or made out by parents or guardians.

Examination. — Candidates whose applications are entertained are submitted in the first half of August to an examination, the syllabus of which is as follows :

	Marks from	Coefficient.
Dictation	0 to 10	4
Addition	do.	1
Subtraction. . . .	do.	1
Multiplication . .	do.	1
Division.	do.	1
Two problems on the four rules .	do.	2
Composition . . .	do.	2

Candidates receiving less than 5 marks are disqualified.

Candidates not disqualified are then classified by adding to the total marks obtained in the examination the following special marks :

a) The son of a deceased employee of the Department	20
A son, son-in-law or grandson, maintained by a present or pensioned employee of the Department . . .	15
The brother, brother-in-law, nephew, or grandson of an employee of the Department whether at present employed, in receipt of a pension or deceased.	10
The son of a deceased employee of another branch of the Department, ar orphan maintained by the State.	15
A son, son-in-law or grandson maintained by a present or pensioned employee of another branch of the service	10
The brother, brother-in-law, grandson or nephew of an employee of another branch of the service, whether at present employed, in receipt of a pension or deceased	5
b) A candidate belonging to a family consisting of :	
Three children under the age of 16	5
Four children under the age of 16	10
Five children under the age of 16	15
Six or more children under the age of 16	20

The additional special marks under *a*) are not cumulative within that group, but marks to which candidates are en-

titled under *a*) are added to those to which they are entitled under *b*).

The classification of the candidates having been thus determined, they are, subject to passing a medical examination, engaged in order of merit, so far as there are vacancies. It is a condition of engagement that they shall, throughout the period of apprenticeship, live with their parents, or some other member of the family, or some other respectable person.

Apprenticeship indentures. — Before entering upon their apprenticeship, which takes place about the 1st October, the apprentices must sign indentures. The indentures must also be signed by their parents or guardian.

By these indentures the parents or guardian undertake that their son or ward shall join the permanent staff of the Company on the expiration of his apprenticeship.

The Company reserves to itself the right to decide, at the end of the first half-year or first year of apprenticeship, for what occupation the apprentice shall be trained (fitter, boilermaker, etc.). In deciding the occupation, account is taken of the particular bent and capacities of the apprentice and of the Company's staff requirements.

II. — Organisation of technical training.

Normal training. — The training given to apprentices consists of technical manual training, supplemented by theoretical courses held during working hours.

The apprentices work for eight hours per day.

Except in exceptional cases the apprenticeship is served entirely at one centre (see Chapter IV). Its normal duration is three years; this period may, however, be reduced in the case of former pupils of technical schools or, as an exception, in the case of apprentices who have already commenced an apprenticeship elsewhere : this reduction, however, depends upon the vacancies which occur during the course of the second and third years. On the other hand, the period of apprenticeship may be extended where an apprentice has been absent through illness so long as to prevent him from acquiring the necessary training to enable him to pass the examinations held at the end of the year.

The complete scheme of technical manual training must normally be followed by every apprentice, in accordance with the established syllabuses, except in the cases mentioned in Chapter V.

As regards the theoretical instruction, apprentices who are unable to complete the whole syllabus may be allowed to take the first or second year theoretical course a second time, or even a third time in the case of the first year course.

Half-yearly examinations. — At the end of each half-year the apprentices undergo an examination on the technical training and theoretical instruction which they have received. The results of this examination, which are taken into account in calculating the half-yearly bonus and in fixing the apprentice's remuneration for the following six months (see Chapter III) are communicated to the parents.

Apprentice's record book (Carnet d'apprentissage). — In the interval between the half-yearly examinations, the parents are kept informed as to the apprentices's work by means of his record book, which is forwarded to them each month by the superintendent of apprenticeship training; and they are required to sign the book and return it after having read the remarks and noted the marks obtained by the apprentice.

III. — **Terms of remuneration.**

The remuneration of an apprentice comprises :

1. a fixed daily wage;

2. a daily working bonus, commencing, however, only with the second year of apprenticeship;

3. a special allowance of so much per actual day's work, varying according to the cost of living in the locality where the apprenticeship is served;

4. a half-yearly bonus, the amount of which depends upon the nature of the results obtained in the half-yearly examinations. The normal bonus is granted when the marks obtained are equal to or higher than 6.5, but less than 7.5, the possible marks ranging from 0 to 10.

An apprentice who obtains average marks of 7.5 or over receives the normal bonus, plus the following increase :

	Increase :
For marks at least equal to 7.5 but less than 8.5.	10 %
— — 8.5 — 9.5.	20 %
— — 9.5	30 %

On the other hand, in the cases of apprentices who obtain less than 6.5 marks, the following reductions are made in the normal bonus :

	Reduction :
For marks less than 6.5 but higher than 5.5	10 %
For marks not more than 5.5 but more than 4.5	30 %
— — 4.5 — 3.5	60 %
— — 3.5 No bonus.	

These bonuses are not paid to the apprentice until the end of his apprenticeship, when they are given to him in the form of a paid-up Savings Bank book.

Increase in wages. — Increases in the daily wage take effect at the beginning of each half-year (1st October and 1st April); they are based on a scale which takes into account the period of apprenticeship served to date and the average marks for manual work obtained in the preceding half-yearly examination.

Increases may be withheld in cases where disciplinary action is necessary (see Chapter V).

IV. — **Holidays.**

Apprentices are not required to work on Sundays and public holidays.

Each year a holiday of from 10 to 15 days may be granted to apprentices at the request of their parents, either between the end of the year-end examinaitons and the re-opening of the courses in the following apprenticeship year, or on the occasion of the yearly holiday of their parents when the latter have not been able to take such holiday during the period just mentioned; but the holiday may not under any circumstances take place during the period of the half-yearly or yearly examinations.

Wages are not paid for public holidays and the yearly holiday.

V. — **Disciplinary measures.**

The disciplinary action which may be taken in regard to apprentices is as follows :

a) Disciplinary action taken by the Engineer in charge of the Locomotive Running Workshops :

1. Censure;

2. Censure, accompanied by a reduction of one-twentieth in the half-yearly bonus, without postponement of promotion, or with postponement of the next succeeding promotion by 1 or 2 months;

b) Disciplinary action taken by the Chief Mechanical Engineer :

3. Final warning, before dismissal, accompanied by postponement for 3 months of the next succeeding promotion, and non-payment of the yearly bonus;

4. Dismissal.

Any misconduct during the 12 months following the giving of a final warning, and subject to disciplinary action more severe than (1), entails immediate dismissal.

All disciplinary action to be taken against an apprentice is notified to him in writing and a copy of the notification is sent to the parents or guardian.

When, during the course of apprenticeship, an apprentice does not obtain more than 3 marks out of 10 in the technical tests, or more than 2 marks out of 10 in the theoretical tests, as an half-yearly average, he may be dismissed on the grounds of inability to profit by the training given. If failure to obtain sufficiently high marks is due to illness, the apprentice is allowed to continue his year if it is a question of the first half-yearly examination, or to recommence his year if it is a question of the year-end examination.

Further, the apprentices are supervised most closely from the beginning of apprenticeship, and particularly during the first two months, and in the case of those who appear definitely incapable of profiting by the training given, or those whose character and conduct are unsatisfactory, the question of immediately terminating their apprenticeship is considered.

VI. — Appointment to permanent staff.

Apprentices who obtain in the manual tests of the final year of apprenticeship average marks (for the course and the examination) of at least 6.5 out of 10 are taken on to the permanent staff as young journeymen. They receive an apprenticeship diploma under the conditions indicated below.

Those who obtain less than 6.5 marks in these tests can only remain with the railway as junior fitters labourers if their marks exceed 3, or as junior labourers, according to age, if their marks do not exceed 3.

VII. — Granting of diplomas on termination of apprenticeship.

Apprentices who are regarded as suitable for employment as young journeyman receive a diploma at the end of their apprenticeship.

This diploma, which is worded as being in respect of both theoretical and practical work, is granted to apprentices who, in their last year of apprenticeship, have obtained separately, in the theoretical tests on the one hand and the practical tests on the other, average marks of at least 6.5 out of 10.

The diploma is marked as being in respect of practical work only in the case of apprentices who have obtained at least 6.5 marks in the practical tests only in the last year of apprenticeship, or who have not followed the complete course of theoretical instruction.

In addition to the reference to « theoretical » or « practical » work, the diploma is also endorsed with the words « Very good », « Good » or « Fair », according to the marks obtained.

APPENDIX VI.

Note in regard to the system of apprenticeship adopted by the Société des Transports en Commun de la Région Parisienne, for the training of drivers and conductors.

In order to obtain the necessary staff for the running of their vehicles and the collection of fares, the Société des Transports en Commun de la Région Parisienne has organized an apprenticeship school for the training of drivers and conductors :

a) DRIVERS.

The training provided for drivers comprises :

1. *A theoretical and practical course of instruction,* lasting from 4 to 15 days according to whether the apprentices are training for the occupation of tram driver or motor omnibus driver.

The theoretical instruction is given to the pupils in a classroom containing the demonstration apparatus necessary for explaining the working of the various parts of the vehicles in question and for initiating the pupils into the method of handling them.

The instructors take particular care to indicate possible sources of mechanical trouble during working, to teach the pupils how to trace them methodically and, so far as possible, to remedy them.

This theoretical instruction is supplemented by a demonstration on a vehicle in running order and by the study of the company's regulations and extracts from the police traffic regulations.

Certain text-books are supplied to the students to assist them in studying the subjects taught.

The theoretical lessons are accompanied by practice runs on instruction vehicles running light.

On each of the instruction vehicles an instructor accompanies a pupil on the driver's seat to supervise and advise him. He endeavours particularly to teach the principles of economical driving and to prepare the pupil for the various incidents which may occur during running in the regular service,. He comments upon the Company's regulations and the police regulations concerning the circulation of vehicles, speed, spacing, order of the road, halts, etc.

2. *An examination* by the Principal Engineer-Inspector of the Control Service of the Local Railways in the case of tram drivers, and an examination by the Inspector of Automobiles in the case of motor omnibus drivers.

3. *Driving in pairs.* — Pupils who pass the examination just mentioned are then detailed to run a service vehicle, under the supervision of a qualified driver, during a period of not less than five days.

4. *Examination by inspector of schools.* — The pupils are then examined by the Inspector of schools for the purpose of ascertaining whether they are now capable of driving alone. If not, they may either be given a further period of training or their apprentisceship may be terminated.

5. *Service driving under supervision.* — During six days the pupils drive in the regular service under the supervision of head driver.

b) CONDUCTORS.

The training provided for conductors comprises :

1. *A theoretical and practical course*

of instruction lasting from 3 to 5 days. — This instruction is given in a classroom equipped for the purpose. It begins with a lecture on the conditions of service of such employees, their duties and their rights; then it deals with the following points :

Fares and stages, order of the road, route maps, method of collecting fares and marking and balancing the fares sheet, duty of the conductor in the happening of various incidents during running, the study of the Company's regulations and extracts from police regulations.

In the course of the practical lessons, the pupils carry out the various duties falling to conductors.

2. *An examination* by the Principal Engineer-Inspector of the Control Service of the Local Railways in the case of tram conductors, and an examination by the Inspector of schools in the case of motor omnibus conductors.

3. Pupils who pass this examination are then sent to the depot to which they will finally be attached. They work on a vehicle of the regular service under the supervision of a regular conductor for a period of not less than 3 days on routes with three stages, 4 days on routes with four stages and 5 days on routes with five or more stages.

The first day the fares are collected by the regular conductor, who points out to the pupil the various features of the route : stages, stopping points, etc.

The second day the pupil holds and delivers the tickets, but the conductor collects the fares, for which he alone is responsible.

From the third day the pupil himself carries out on an easy route all the duties of conductor, under the supervision and advice, and where necessary with the assistance, of the regular conductor who accompanies him.

4. *An examination by the Inspector of schools.* — After this practice in the company of a regular conductor, the pupils are examined by the Inspector of schools and, where necessary, they may either be required to undergo a further period of training or their apprenticeship may be terminated.

5. *Conducting in the regular service under supervision.* — Following the examination by the Inspector of schools, the pupils become probationary conductors, and their work is specially supervised for one month by a school controller.

During the period of their apprenticeship, the driver-apprentices and conductor-apprentices receive remuneration at the maximum rate of 14 francs per day of actual work.

This remuneration is paid to the pupils even if their apprenticeship is terminated before they have reached the stage of working independently, except in cases where they are dismissed for misconduct. On the other hand, no remuneration is paid to them if they leave the service of the Company of their own accord before reaching the stage of independent working.

Further, after three months' actual work, counted from the date on which they first work independently, they receive additional remuneration of 2.50 francs per day of apprenticeship.

Motor omnibus drivers are required to refund the cost of their driver's licence, together with the remuneration paid to them during their apprenticeship, if they do not remain in the Company's service for at least two years.

In the year 1927, 2 380 conductors and 633 drivers were trained in this way.

[625. 614]

REPORT No. 2

(All countries, except Europe)

ON THE QUESTION OF THE IMPROVEMENTS IN THE PERMANENT WAY EQUIPMENT OF LIGHT RAILWAYS (SUBJECT XVIII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

By Mostafa Bey Hamdi EL KATTAN,
CHIEF ENGINEER FOR PERMANENT WAY AND WORKS OF THE EGYPTIAN STATE RAILWAYS.

The questionnaire sent in our name to the various Railway Companies operating Light Railways is as follows :

1. — What was the type of permanent way and rolling stock used when your light railways were built, and what improvements and betterments have been introduced to the present time ? Attach drawings as necessary.
2. — Do you use any system of signals for working your line? This system, is it the same as that originally used? If not, indicate the improvements made.
3. — How was the maintenance of your line and rolling stock carried out at first? Have you improved the methods and if so in what way ?

26 replies have been received. They are summarised in tables I, II and III below.

Question I.

Improvements carried out to the permanent way and rolling stock.

As regards permanent way (rails and fittings) table I shows that whereas originally the weight of rail varied from 6.5 kgr. to 27.6 kgr. per metre (13.1 to 55.6 lb. per yard), it has gradually been increased to 36 kgr., 40 kgr. and even up to 55 kgr. per linear metre (72.6, 80.6 and 110.9 lb. per yard). This last figure, has been given by the *Wabash Railway Company* in the United States. This Company has not given any information as to its gauge, and in view of the weight of the rails (55 kgr.) now used, this Railway can hardly be classified among the light railways, unless the gauge of its track should be less than 1.50 m. (4 ft. 11 1/16 in.).

The *South African Railways and Harbours* have increased to 40 kgr. (80.6 lb.) the weight of rail which was originally 22 kgr. (44.3 lb.). The gauge was originally 1.06 m. (3 ft. 6 in.) and has not been altered.

As regards rolling stock, the weight of the locomotives has in most cases followed the increase in weight of the rails.

For example to quote only the *South African Railways*, the heaviest axle load was originally 18.5 metric (18.2 English) tons, and is now 22 metric (21.7 English) tons, corresponding to a rail which

(1) Translated from the French.

weighs 40 kgr. per m. (80.6 lb. per yard), whereas originally the weight was 22 kgr. (44.3 lb.).

In the same way the *Ivory Coast Railways*, the rails of which weighed 20 kgr. (40.3 lb. per yard) originally, and now weigh 30 (60.5 lb.), have increased the weight of their locomotives from 19.5 t., to 32 t. (19.2 to 31.5 English tons).

This, however, is not a general rule, as we note that on the *Lower Congo to Katanga*, and the *Upper Congo to the Great African Lakes* Railways, the rails [29 kgr. (58.5 lb.) for the first Company, and 24 kgr. (48.4 lb.) for the second] are at the present time, the same as when these Railways were built.

These two Companies are now using locomotives the first weighing 138 metric (135.8 English) tons, with tender, instead of 89 metric (87.6 English) tons with tender, and the second locomotives weighing 53 metric (52.2 English) tons in place of the original engines, which weighed 22 t. (21.7 English tons).

Question II.

System of signals used.

From table II it will be seen that most light railway companies have no system of signalling properly speaking.

Some of the railways use green and red flags during the day, and lanterns of the same colour, during the night.

Others use discs as advance signals or as repeaters.

Three railways alone, out of the 26, use the absolute block system.

Question III.

Maintenance of the track and of the rolling stock.

The replies received, and which are summarised in table III, show that no improvements have been introduced as regards maintenance of the track or in the way the rolling stock is repaired.

CONCLUSIONS.

From the foregoing and the reports that we have received with regard to the equipment of the permanent way of light railways in countries other than Europe, it appears that, as a general rule, the equipment of these lines outside the few cases we have quoted, have not undergone any great improvement.

This is probably due to the fact that the amount of traffic has not increased; as a consequence, the equipment of these lines has remained in its original state.

TABLE I.

Permanent way and rolling stock.

Name of the Company.	Equipment.	Original.	Present day.
Reunion Railway . . .	Gauge.	Metre (3 ft. 3 3/8 in.).	Metre.
	Rails and fittings.	14 kgr. (28.2 lb. per yard), on pot sleepers.	25 kgr. (50.4 lb. per yard) on metal sleepers.
	Locomotives.	6 wheeled coupled, 15 t. (14.7 Engl. tons).	8 wheeled coupled, 20 t. (19.7 Engl. tons).
Japanese Government Railways.	Gauge.	3 ft. 6 in.	3 ft. 6 in.
	Rails and fittings.	23 kgr. (46.4 lb. per yard) on 7 ft. × 5 ½ in. × 7 in. sleepers.	37.5 kgr. (75.6 lb. per yard) on 7 ft. × 5 ½ in. × 8 in. sleepers.
	Depth of ballast under the sleepers.	Over 0.15 m. (6 inches).	Over 0.15 m. (6 inches).
	Kind of ballast.	Gravel.	Gravel.
	Dimensions of ballast.	12 to 62 mm. (1/2 to 2 7/16 inches).	12 to 62 mm. (1/2 to 2 7/16 inches).
	Width of the road bed at the top.	4.20 m. (13 ft. 9 3/8 in.).	4.20 m. (13 ft. 9 3/8 in.).
	Heaviest axle load.	10 t. (9.8 Engl. tons).	15 t. (14.7 Engl. tons).
Ivory Coast Railways .	Gauge.	...	...
	Rails.	20 kgr. (40.3 lb. per yard).	30 kgr. (60.5 lb. per yard).
	Locomotives.	12 t., 15 t., 17 t. and 19.5 t. (11.8, 14.8, 16.7 and 19.2 Engl. tons).	19.5 t., 27 t. and 32 t. (19.2, 26.5 and 31.5 Engl. tons).
South African Railways & Harbours.	Gauge.	3 ft. 6 in.	3 ft. 6 in.
	Rails and fittings.	22 kgr. (44.3 lb. per yard), on wooden sleepers.	40 kgr. (80.5 lb. per yard) on wooden sleepers.
	Depth of ballast under the sleepers.	0.125 m. (5 inches).	0.20 m. (8 inches).
	Dimensions of the sleepers.	...	0.25 m. × 0.125 m. × 2.10 m. (10 in. × 5 in. × 6 ft. 10 in.).
	Heaviest axle load.	18.5 t. (18.2 Engl. tons).	22 t. (21.6 Engl. tons).

Name of the Company.	Equipment.	Original.	Present day.
Conakry to the Niger Railway.	Gauge.	...	...
	Rails and fittings.	25 kgr. (50.4 lb. per yard) on wooden sleepers.	26 kgr. (52.4 lb. per yard) on wooden sleepers.
French Dahomey Railway Co.	Gauge.	Metre.	Metre.
	Rails and fittings.	22 kgr. (44.3 lb. per yard) on metal sleepers.	22 kgr. (44.3 lb. per yard) on metal sleepers.
	Locomotives.	6 wheeled coupled of 30 t. (29.5 Engl. tons) and 4 coupled of 18 t. (17.7 Engl. tons).	6 wheeled coupled of 30 t. (29.5 Engl. tons) and 6 coupled of 37 t. (36.4 Engl. tons).
East Dahomey from Porto-Novo to Pobé Railway.	Gauge.	Metre.	Metre.
	Rails and fittings.	22 kgr. (44.3 lb. per yard) on metal sleepers.	22 kgr. (44.3 lb. per yard) on metal sleepers.
	Locomotives.	15 t. (14.8 Engl. tons). 20 t. (19.7 Engl. tons). 40 t. (39.4 Engl. tons).	15 t. (14.8 Engl. tons). 20 t. (19.7 Engl. tons). 40 t. (39.4 Engl. tons).
Tunisian Railway Company.	Gauge.	Metre.	Metre.
	Rails and fittings.	20 kgr. (40.3 lb. per yard) on oak sleepers.	36 kgr. (72.6 lb. per yard) on metal sleepers of 39 kgr. (86 lb.).
	Rolling stock.	Composite coaches 6 and 12 t. (5.9 and 11.8 Engl. tons) tare weight.	Composite coaches of 26 t. (25.5 Engl. tons) tare weight. Bogie wagons of 30 tons capacity.
Wabash Railway (U. S. A.).	Rails and fittings.	Vignoles rails of 6 1/2 kgr. (13.1 lb. per yard) on wooden sleepers.	Vignoles rails of 55 kgr. (110 lb. per yard) on creosoted wooden sleepers and ballast.
Nigerian Railway . .	Gauge.	2 ft. 6 in.	2 ft. 6 in.
	Locomotives.	...	16 tons axle load.
Bombay, Baroda & Central India Railway Company.	Gauge.	2 ft. 6 in.	2 ft. 6 in.
	Locomotives.	Weight with tender 18 1/2 tons.	41 tons.

Name of the Company.	Equipment.	Original.	Present day.
North Western Railway (India).	Gauge.	2 ft. 6 in.	2 ft. 6 in.
	Rails and fittings.	...	...
	Locomotives.	Weight 21 tons.	On four coupled wheels, 50 tons. Weight of the locomotive 70 tons.
Chôsen Government Railways.	Gauge.	2 ft. 6 in.	2 ft. 6 in.
	Rails and fittings.	12 1/2 kgr. (25-lb. per yard). Vignoles rails.	15 to 17 1/2 kgr. (30 to 35 lb.) Vignoles rails.
	Locomotives.	Weight 12 tons.	Weight 17 tons.
Bengal & North Western Railway.	Gauge.	Metre.	Metre.
	Locomotives.	13 tons.	50 tons.
Great Indian Peninsula Railway.	Gauge.	2 ft. 6 in.	2 ft. 6 in.
	Rails and fittings.	16 kgr. (32 lb. per yard). Vignoles rails on metal sleepers.	No change.
	Locomotives.	40 tons.	Locomotive and tender 36 tons.
Eastern Bengal Railway.	Gauge.	2 ft. 6 in.	2 ft. 6 in.
	Rails and fittings.	...	...
	Locomotives.	Four wheeled coupled of 9.95 tons.	Four wheeled coupled of 8.9 tons.
Egyptian Delta Light Railways.	Gauge.	2 ft. 6 in.	2 ft. 6 in.
	Rails and fittings.	13 1/2 kgr. (27.2 lb. per yard). Vignoles rails on wooden sleepers.	16 kgr. (32.2 lb. per yard) Vignoles rails. on wooden sleepers.
	Locomotives.	...	11 t. (10.8 Engl. tons).
Lower Egyptian Railway Company.	Gauge.	Metre.	Metre.
	Rails and fittings.	21 kgr. (42.3 kgr. per yard) Vignoles rails	No change.
	Locomotives.	...	...
Smyrna to Cassaba and extension Railway.	Gauge.	...	...
	Rails and fittings.	Iron rails.	30 and 34 kgr. (60.5 and 68.5 lb. per yard) Vignoles rails on metal sleepers.

Name of the Company.	Equipment.	Original.	Present day.
Dutch East Indies Railway.	Gauge.	3 ft. 6 in.	3 ft. 6 in.
	Rails and fittings.	25.7 kgr. (51.8 lb. per yard) rails on wooden sleepers.	No change.
	Locomotives.	...	Total weight 42 t. (41.3 English tons).
Damas-Hamah and Extensions Railway.	Gauge.	1.05 m. (3 ft. 5 3/8 in.).	No change.
	Rails and fittings.	27.6 kgr. (55.6 lb. per yard) Vignoles rails on metal sleepers.	...
	Locomotives.	...	Weight 52 t. (51.2 Engl. tons).
Fayoum Light Railways (Egypt).	Gauge.	0.75 m. (2 ft. 5 1/2 in.).	0.75 m. (2 ft. 5 1/2 in.).
	Rails and fittings.	16 kgr. (32.2 lb. per yard) Vignoles rails on wooden sleepers.	18.20 and 22 kgr. (36.7 and 44.3 lb. per yard) Vignoles rails on wooden sleepers.
Paris, Lyons & Mediterranean Railway (Algerian lines).	Gauge.	1.05 m. (3 ft. 5 3/8 in.).	No change.
	Rails and fittings.	25 kgr. (50.4 lb. per yard) Vignoles rails on wooden sleepers.	...
	Locomotives.	...	...
Lower Congo to Katanga Railway.	Gauge.	3 ft. 6 in.	3 ft. 6 in.
	Rails and fittings.	42 kgr. (84.7 lb. per yard) Vignoles rails on metal sleepers, 1 200 per km. (1 930 per mile).	29 kgr. (58.5 lb. per yard) Vignoles rails on metal sleepers, 1 500 per km. (2 413 per mile).
	Locomotives.	Weight 80 t. (78.7 Engl. tons) with tender.	Weight with tender 138 t. (135.8 Engl. tons).
Upper Congo to the Great African Lakes Railway.	Gauge.	Metre.	Metre.
	Rails and fittings.	24 1/2 kgr. (49.4 lb. per yard) Vignoles rails on wooden sleepers.	24 1/2 kgr. (49.4 lb. per yard) Vignoles rails on metal sleepers.
	Locomotives.	Weight 22 t. (21.6 Engl. tons).	Weight 53 t. (52.2 Engl. tons).
Thiès to the Niger Railway (French West Africa).	Gauge.	Metre.	Metre.
	Rails and fittings.	20 and 25 kgr. (40.3 and 50.4 lb. per yard) rails on metal sleepers.	26 kgr. (52.4 lb. per yard) rails on wooden sleepers.
	Locomotives.	Weight 26 t. (25.6 Engl. tons).	Weight 47 1/2 t. and 38 t. (46.7 and 37.4 Engl. tons).

Table II. — **Signalling**.

Name of the Company.	*Information supplied.*
Reunion Railway	*Hand signals.* A green or red flag during the day. A lamp showing a white, green or red light as desired at night. *Fixed signals.* Advanced disc is provided intended to indicate the neighbourhood of stations, junctions, etc. : *a*) Metal disc turning about a pivot, able to occupy two positions, one parallel to, the other at right angles to the track; *b*) discs in wood, fixed at right angles to the track, used as a rule, to indicate a speed restriction. N. B. — These discs have not yet been installed. The system using flags is still in use. The protection of the trains is covered by telephonic sections.
Japanese Government Railways.	Two types of fixed signals are in use. The home signal and the starting signal. The first is used at stations where trains pass one another, and the second in special cases when necessary. As regards the block system, the staff or the staff and ticket were formerly in use; latterly, in order to facilitate the operation of the double track lines, the telegraph block system and the automatic block signal system have been adopted.
Ivory Coast Railways	*Visible signals.* Green, white and red flags during the day. By lights of the same colour at night. *Fixed visible signals.* The only ones used are advanced signals consisting of a fixed disc with a red and white face, intended to protect the stations and any other necessary points.
Konakry to the Niger Railway.	The system of signals used in the main stations consists of an advance signal in the form of a moveable red disc, and a moveable repeater signal square shaped in red and white squares, with a locking equipment. The system used in the secondary stations consists of an advance signal in the form of a green and white square disc, and a red stop signal disc close to the entrance into the station. This system was fitted originally and has not been altered in any way, except in the main stations, where the system described above was installed in 1912.
French Dahomey Railway Company.	No system of signalling was fitted when the Railway was built, and the small number of trains has not yet made it necessary to consider any such system of signalling.

Name of the Company.	*Information supplied.*
East Dahomey from Porto Novo to Pobé Railway.	Has not given any information.
Thiès to the Niger Railway . .	Only advance signals with round discs painted red placed near all stations. The speed restriction signals used up to the present are moveable. Arrangements are being made to fit in the near future, absolute stop signals repeating certain advance signals. The type will be that used by the French Railways.
Tunisian Railway Company .	The system of signals includes first of all square signals (red and white check) with lamps showing two red, or two white lights according to the case. At the present time, the system of signals includes, or will include : Red discs for caution. Square signals for stop. Semaphores to maintain the correct interval between trains. Speed indicator boards. Junction indicators. Square green and red check signals to announce the approach of a semaphore or of a definite stop signal. Direction indicator signals placed at facing points. Indicator signals indicating the position of points. Indicators for passing at speed. Setting back signals.
Algerian Railways of the State .	Fixed semaphores (List and Morse) on the main line. Double wire system will be installed on new lines.
Bombay, Baroda & Central India Railway.	A system of signals has been adopted for the operation of these lines. No change has been made in the system.
North Western Railway (British India).	A system of signalling is in use. No change has been made.
Chôsen Government Railway (Corea).	Flags during the day. Lamps during the night. No change made.
The Bengal & North Western Railway.	No information.

Name of the Company.	*Information supplied.*
Great Indian Peninsula Railway.	In all the stations, an advance semaphore at each end of the station is fixed. It is worked by hand. 24 to 30 feet high. No change made.
Eastern Bengal Railway.	An advance signal at each end of the station at a distance of about 500 feet from the facing points, worked from the platform. No change in the original system.
Egyptian Delta Light Railways.	The speed of the trains being low, signals are only provided at swing bridges over the canal, level crossings, etc.
Lower Egypt Railway	Hand operated signals in the important stations at crossings or at junctions.
Smyrna to Cassaba Railway .	No general system of signalling. Semaphores at the entrances to important stations only. Slight modifications have been made.
Dutch East Indies Railway . .	No signals originally. At the present time there are several at the entrance to the principal stations with or without advance signals.
Damas-Hamah Railway and extensions.	Advance signals with moveable arms to indicate the approach to a station. Latterly, some stations have been fitted with absolute stop signals.
Fayoum Light Railways (Egypt).	No signals properly speaking. Two advance semaphores at the two main stations.
Paris, Lyons & Mediterranean Railway (Algerian lines).	Advance discs at the stations and position signals for facing points.
Lower Congo to Katanga Railway.	Originally, fixed signals. At the present time, a disc stop signal worked from a distance by wire in the stations and holding sidings. In the main stations mechanical signals worked from a signal box.
Upper Congo to the Great African Lakes Railway.	Originally, no signalling. Signals have recently been provided near bridges, near water columns, main stations, etc.
French Dahomey Railway Company.	No signals, except at the branch from Pahou and at Cotonow. A round disc in front of a square red and white check signal.

Name of the Company.	Information supplied.
South African Railways & Harbours.	The system of signalling is based on the system of line occupied or absolute block; in addition stop signals protect all the trains. The system of signalling since the formation of the South African Union in 1910 is the « Upper Quadrant two positions semaphore signal ». The stations where the operation is single line, has absolute stop signals with two arms, enabling a train to run on to the loop or on the line according to the case. Departure signals are not used where single line working is in force. At single line junctions, departure signals are not used; but on the other hand a special type of signal is used to indicate the junction. In cases where the number of trains is great, and where through trains run, an advance signal is placed under the outer stop signal. Double direction point indicators are used where trains cross.

Table III. — **Maintenance of the track and the rolling stock**

Reunion Railway	*Maintenance of the track.* Originally one man per km. (0.621 mile). At the present time one man for 2 km. (1.242 miles). *Rolling stock.* Maintained by a special service known as the « Locomotive running ». Heavy repairs, carried out by the workshops at the Port.
Japanese Government Railways.	The roadmaster looks after 50 miles of track. The track supervisor is responsible for the maintenance of 15 miles. Each *track section* consists of 5 to 10 men under the control of a *section foreman.* The number of *track sections* is from 3 to 5. The maintenance of the track is organised by the office of the Chief Engineer, whilst the upkeep of the structures is in the hands of contractors. The arrangements quoted above, have not been altered. The ordinary upkeep of the rolling stock is carried out in a locomotive shed, the heavy repairs are carried out in workshops equipped for this purpose.

Name of the Company.	Information supplied.
Ivory Coast Railway	*Staff.* A Head of the permanent way service. A District Superintendent per 200 km. (124 miles). A Section Inspector, for every 40 to 50 km. (25 to 32 miles) of one part of the line, and every 60 or 70 km. (37 to 43 miles) of the second part. *Native staff.* One man per km. (0.621 mile), one gang per 6 or 7 km. (3.7 to 4.3 miles). *Rolling Stock.* Until 1908, no maintenance department had been organised. As from 1909, arrangements were made to carry out heavy repairs to the locomotives in the Abidjan worshops. The average figure of 120 000 train-km. (75 600 train-miles) was allowed as the maximum for heavy repairs at the work shops. *Vehicles.* Running repairs carried out by the running repair staff of each depot. General overhaul every two years. Heavy repairs every four years.
South African Railways & Harbours.	*Maintenance of the track.* Each permanent way inspector is responsible for 100 to 150 miles of track. For every four miles of main line, and each 10 miles of secondary lines, there was originally a ganger with 6 to 12 men according to circumstances. When relaying lines, ballasting, etc., each permanent way inspector had under his control two gangs composed of 30 to 45 men including a ganger and his assistant. No change has been introduced since, except that a flying squadron has been organised for secondary lines with little traffic.This gang consists of a ganger, his assistant, and 9 to 16 men travelling by motor trolley with trailer from one point to another. The maintenance of 25 to 40 miles is covered in this way. The maintenance of the rolling stock is carried out in the workshops of the various Companies.These shops have been enlarged so that they can carry out efficiently the maintenance required by the present increase in traffic.
Konakry to the Niger Railway.	*Track.* Originally the maintenance of the track was carried out by large travelling gangs of 25 to 30 men, under the orders of district inspectors. Later replaced by small gangs of 9 to 10 men responsible for the maintenance of the 10 km. (6.2 miles) of track under their care. *Rolling stock.* From the beginning up to the present time, the maintenance is covered by: 1. a gang for ordinary maintenance, 2. a second gang for heavy repairs. On the average, every vehicle is lifted every five years.

Name of the Company.	*Information supplied.*
French Dahomey Railway Company.	*Track.* Four men under a ganger for a distance of about 8 km. (5 miles). These gangs are under the supervision of European district superintendents, and a permanent way inspector. *Rolling stock.* The rolling stock has always been repaired at the shops at Cotonow.
East Dahomey, from Porto Novo to Pobé Railway.	*Track.* Prior to 1926, the track was maintained according to the needs of the moment. Subsequently, the maintenance of the Main Line and service lines has been organised on the lines of the French Railways.
Thiès to the Niger Railway .	*Rolling stock.* There is a central work shop at Thiès, and a number of gangs out on the line at considerable distances away. Electrified workshops are now being completed at Thiès.
Tunisian Railway Company .	*Track.* Until 1914, the upkeep was carried out as needed, or by travelling gangs. At the present time, repair work is done on methodical lines or the track relaid (period six months, cycle of three, or four years, according to the importance of the line). As from 1925 a test has been made of carrying the maintenance staff on automobile trollies over a 40-km. (25 miles) section. The first results have been satisfactory. *Rolling stock.* By a gang for light repairs in the stations. Heavy repairs carried out in the principal workshops.
Wabash Railway (U. S. A.) .	*Rolling stock.* Originally there were three shops where repairs to locomotives and vehicles were carried out. At the present time the workshop at Decatur has been enlarged and brought up to date; all repairs to rolling stock are now carried out in these workshops.
Nigerian Railway	The method of maintaining the track has not changed since the line was built. European head gangers supervise sections varying from 28 to 60 miles in length. These sections are under the control of native gangers, four miles per ganger. There are 3.28 men per mile of track.
Bombay, Baroda & Central India Railway Company.	*Track.* Originally, gangs composed of a ganger and 5 men for each 3 1/2 miles of track. Each permanent way inspector controlled 50 miles. There has been no change in the organisation.
North Western Railway (British India).	*Track.* From 1 to 2 men per mile of track. Several gangs are under the supervision of an inspector and two inspectors under a district foreman. *Rolling stock.* Ordinary repairs are carried out at Kalka. Heavy repairs are carried out in the main workshops at Moghalpura.

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Name of the Company.	*Information supplied.*
Chosen Government Railway (Corea).	No information.
The Bengal & North Western Railway.	Originally, all repairs to rolling stock were carried out at Sonepore. In 1907 and 1914, modern work shops were built at Gorakhpur. All the machinery is driven by electricity.
Great Indian Peninsula Railway.	*Track.* A foreman ganger and 1 3/4 men per 4 miles of track. No alterations since the line was built. *Rolling stock.* Small repairs and ordinary running maintenance in small shops. Heavy repairs in the main workshops.
Eastern Bengal Railway . . .	From the opening of the line up to the present, permanent gangs living alongside the line, look after the maintenance of the track. On some lines where the track was originally not laid on ballast, these lines have since been ballasted.
Egyptian Delta Light Railways.	*Track.* Each permanent way inspector controlls 70 to 80 km. (43 to 50 miles). The Inspectors have under their orders a gang composed of a ganger, and 5 men per 8 km. (5 miles) of track. This method has not changed since the line was opened. *Rolling stock.* There are three districts, and each district includes a locomotive shed and a workshop where maintenance and repairs to rolling stock are carried out. This system adopted in the beginning is still in force with improvements introduced from time to time.
Lower Egypt Railways . . .	*Track.* Maintenance is covered by gangs of 7 men, one ganger and 6 men, for sections of from 10 to 12 km. (6.2 to 7.4 miles), according to the nature of the formation. *Rolling stock.* Locomotives. { Light repairs after 30 000 km. (18 500 miles). Heavy repairs after 100 000 to 150 000 km. (62 000 to 93 000 miles). Wagons. As required.
Smyrna to Cassaba & Extension Railway.	*Track.* No information on the practice when first built : at the present moment by carrying out repairs as found necessary. *Rolling stock.* No information as to the original method. At the present time ordinary maintenance is covered by examiners attached to the principal stations and by a special gang stationed at Smyrna for heavy repairs.

Name of the Company.	*Information supplied.*
Dutch East Indies Railway . .	Maintenance of the track on the Djocja-Willem I-Parakan line is covered in the following way : The engineer, 2 district engineers, 5 supervisors. — 14 gangs for a total distance of 110 km. (68 miles), each gang being formed of a ganger and assistant and 4 to 6 men. The whole of this personel is under the control of the maintenance engineer.
Damas-Hamah & Extensions Railway.	*Track.* 8 to 9 men per 9 km. (5.6 miles) of track. At the present time one ganger, one assistant and 5 men for 12 km. (7.5 miles) of track, on the rack section, and per 15 km. (9.3 miles) on the adhesion lines.
Fayoum Light Railways (Egypt).	*Track.* One ganger, and 3 to 4 men per 12 to 16 km. (7.5 to 10 miles) of track. *Rolling stock.* Running repairs of locomotives in service : 1 gang of 1 fitter, 1 helper, and 1 apprentice. Light and heavy repairs : A gang of 4 fitters with 1 apprentice.
Paris, Lyons & Mediterranean Railway (Algerian lines).	*Track.* 1 chief ganger and 4 gangers per 8 km. (5 miles) of track.
Lower Congo to Katanga Railway.	*Track.* Since the opening of the line, upkeep as required has been the practice. Upkeep by complete relaying is under test. *Rolling stock.* Light repairs are made at examination centres and depots at various points along the line. Heavy repairs are carriied out in central workshops at Headquarters.
Upper Congo to the Great African Lakes Railway.	The maintenance of the track is covered by a flying gang who have to look after a given length of track. Originally wooden sleepers were used, but these at the present time are being replaced by metal sleepers. The line has been ballasted for a number of years.

MISCELLANEOUS INFORMATION

[385. (06.3 55 & 669]

International Mining, Metallurgy and Applied Geology Congress.

During the International Exhibition which will take place at Liége in 1930, the Association of Engineers graduated at the Liége School (A. I. Lg.) and the Geological Society of Belgium at Liége, have been given the duty of organising the 6th Session of the International Mining, Metallurgy and Applied Geology Congress.

This Session, of which His Majesty King Albert and the Belgian Government have agreed to be Patrons, will open at the end of June 1930 and will last for about one week.

It will consist of full meetings, sectional meetings, visits of technical interest, receptions and various other functions.

General mechanical Science will be in 1930 the object of a special Congress, instead of following the procedure of the last two sessions.

The Offices of the General Secretary of the Congress, have been opened at Liége, quai des Etats-Unis, 16, to which address, enquiries for information should be sent.

NEW BOOKS AND PUBLICATIONS.

[385. 5 (.3)]

Universal Directory of Railway Officials, 1929. — One volume (8 1/2 × 5 1/2 inches) of 400 pages, — 1929, London, The Directory Publishing Company Limited, 33, Tothill street, Westminster. S. W. 1. — Price : 20 sh. nett.

It is no longer necessary to introduce to the readers of the Bulletin, this publication, which has been for a long time well known to those who have to deal with Railways, whether as operators, or as builders, or as contractors.

The 35th annual edition prepared with the same care as the preceeding volumes, in an elegant and easily consulted single volume, has been brought up to date, and carefully checked by means of information taken from official sources under the direction of the Editor of the *Railway Gazette*.

It contains the names, official titles and addresses with an indication of the place where their offices are located, of all Officials placed at the head of the principal departments of the Public Administrations, and of the Railway Companies, of the whole World, as well as of the staff controlling the Institutions, Associations, and Societies founded by railwaymen. No other publication supplies such full information. In it, are also to be found brief notes on the principal features of each Railway : length of line, gauge, rolling stock.

Companies dealing with railway materials, use this directory constantly. By it, any one can readily find the Railway for which he is looking, and the Official competent to deal with the matter in question. Universal by its subject, it is also universal by the way it is distributed throughout the Railway World.

E. M.

[621 .33 & 623].

STABARIN (Alberto), Engineer, Lt.-Colonel of Engineers. — **Considerazioni militari sull' elettrificazione delle ferrovie (Military questions involved in the Electrification of Railways).** Extract from the *Rivista Militare Italiana*. A pamphlet of 16 pages.—1928, Rome, Tipografia Regionale.

The author in this pamphlet considers the effect of railway electrification on the military defense of a country.

He gives the chief characteristics of the different systems used. He notes for example that the distance between the substations varies considerably in the various systems.

Having reminded the reader of the opinions of several writers and the steps that have been proposed : continued use of steam traction in frontier districts, formation of a park of steam locomotives as a standby with a trained staff, he discusses the advisability of such measures, and the importance of various factors, such as the use of uniform current, the selection of industrial frequency current, the ratio of the total production to the consumption by the railways, and

finally the length of the electrified lines to that of the whole system.

The author considers that on the whole there are advantages in electrification which counterbalance the drawbacks from a military point of view, and that the latter can be further minimised by taking suitable measures beforehand.

E. M.

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[655].

STABARIN (Alberto), Engineer, Lt.-Colonel of Engineers. — **La Federazione internazionale della stampa tecnica e il suo IV° Congresso (The international Technical Press Federation and its IVth Congress)** Extract from the *Rivista d'Artiglieria e Genie.* A pamphlet of 20 pages. — 1929, Rome, Arti grafiche Ugo Pinnaro, Via degli Scipioni, 126.

This article gives a short account of the IVth Congress held by the International Technical Press Federation (F.I. P.T.) at Geneva in 1928. This Federation was founded in 1925 during the first Congress held in Paris, the permanent headquarters being established in that city.

The choice of Geneva for the IVth Congress was inspired by a desire to strengthen the bonds of union which unite the F.I.P.T. and other international organisations, especially the League of Nations, which encouraged its labours and took part in them.

The work of examining the questions brought before the Congress was divided between four committees whose spheres of action was thus defined :

First Committee : organisation, propaganda, and statistics;

Second Committee : questions relating to the post and procedure to be followed;

Third Committee : juridical and economical questions;

Fourth Committee : advertising.

Among the points dealt with we must mention the definition of the technical press, the question of the interchange of technical revues, that of reprinting articles borrowed either entirely or in part, the formation of information bureaux, and a proposal of the International Institute for the scientific organization of labour to unify the different characteristics of the periodicals.

E. M.

[313 : 656.2]

BIRAGHI (Pietro), Engineer. — **L'Informazione statistica nei trasporti. Neccessita e metodo dei relievi. (Statistical Information on Transportation questions. Need for and grouping of the various statistical elements)** A pamphlet of 24 pages. — 1928, Città di Castello, Tipografia dell' « Unione Arti Grafiche ».

The author makes a very valuable contribution to the question of statistics in the transportation industry. Statistics to be of use should be instructive, that is to say they should give the operator particulars of the working of the undertaking as a whole and in its different departments and should place him in such a position as to be able to take the necessary steps or decisions required under different circumstances. They must be readily understandable and therefore much care must be given to their preparation and presentation.

The author divides the statistical information into three main classes :

I. Data relative to the railway, its permanent way and rolling stock.
This information is of a permanent character or has periodic changes.

II. Operating results.

III. Staff questions.

He then indicates in detail the information to be shown in each class. He points out all the numerical lata to be collected or to be prepared in order to draw up statistical statements each detail of which, has a clear and precise meaning and is of value to the person for whom it is intended.

E. M.